6. Materials Technology

The Vehicle Technologies Office (VTO) supports research, development, deployment, and demonstration (RDD&D) of new, efficient, and clean mobility options that are affordable for all Americans. The office's investments leverage the unique capabilities and world-class expertise of the national laboratory system to develop new innovations in vehicle technologies, including: advanced battery technologies; advanced materials for lighter-weight vehicle structures and better powertrains; energy-efficient mobility technologies and systems (including automated and connected vehicles as well as innovations in connected infrastructure for significant systems-level energy efficiency improvement); combustion engines to reduce greenhouse gas (GHG) emissions; and technology deployment and integration at the local and state level. In coordination with the other offices across the Office of Energy Efficiency and Renewable Energy (EERE) and the U.S. Department of Energy (DOE), the Vehicle Technologies Office advances technologies that assure affordable, reliable mobility solutions for people and goods across all economic and social groups; enable and support competitiveness for industry and the economy/workforce; and address local air quality and use of water, land, and domestic resources.

The Materials Technology subprogram supports the Vehicle Technologies Office goals of achieving 100 percent decarbonization of the transportation sector by 2050. This ambitious goal will be realized through the increased deployment of electric and hydrogen fuel cell vehicles. Materials play an important role in increasing the efficiency of electric vehicles through weight reduction as well as enabling additional functionality such as faster charging and new sensing technologies. Lighter weight vehicle structures and electric drivetrains will require fewer batteries to achieve the same range, which in turn reduces battery cost, material needs, and reduces the greenhouse gas emissions from battery production. Functional materials with improved properties such as electrical conductivity, thermal conductivity, and unique sensing capabilities will enable innovations in charging and autonomous vehicles. The materials and manufacturing methods used to make vehicles also contribute to greenhouse gases and the Materials Technology subprogram supports research, development, and deployment to increase recyclability and reduce the overall embodied energy of vehicles. The Materials Technology subprogram accomplishes its technical objectives through research programs with academia, national laboratories, and industry.

Lightweight Materials supports national laboratory, academia, and industry-led research in advanced high-strength steels, aluminum (Al) alloys, magnesium (Mg) alloys, carbon fiber composites, and multi-material systems with potential performance and manufacturability characteristics that greatly exceed today's technologies. This includes projects addressing materials and manufacturing challenges spanning from atomic structure to assembly, with an emphasis on establishing and validating predictive modeling tools for materials applicable to light- and heavy-duty vehicles.

Powertrain Materials supports research at national laboratories, academia, and industry to develop higher performance materials to address the future properties needs of electric and hydrogen fuel cell vehicles to increase efficiency and decrease manufacturing cost, supporting the transition to all electric light duty vehicles by 2035. Research funded through this activity applies advanced characterization and multi-scale computational materials methods, including HPC, to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for lighter and more efficient powertrains.

Project Feedback

In this merit review activity, each reviewer was asked to respond to a series of questions, involving multiple-choice responses, expository responses where text comments were requested, and numeric score responses (*on a scale of 1.0 to 4.0)*. In the pages that follow, the reviewer responses to each question for each project will be summarized: the multiple choice and numeric score questions will be presented in graph form for each project, and the expository text responses will be summarized in paragraph form for each question. A table presenting the average numeric score for each question for each project is presented below.

Table 6-1 – Project Feedback

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat146	Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites	Vlastimil Kunc (ORNL/Ames Laboratory)	6-9	2.83	2.83	2.67	2.83	**2.81**
mat149	Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components	Scott Whalen (PNNL/LBNL)	6-13	3.50	3.50	3.50	3.38	**3.48**
mat151	Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints	Adam Powell (Worcester Polytechnic Institute/ LANL)	6-17	2.88	3.38	3.25	3.00	**3.19**
mat152	A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives	Roozbeh Dargazany (Michigan State University/ NREL)	6-20	3.10	3.30	3.50	2.60	**3.19**
mat153	Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints	Miki Banu (University of Michigan/ ORNL)	6-24	3.63	3.50	3.75	3.50	**3.56**
mat162	Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys	Dongwon Shin (ORNL)	6-28	2.67	3.00	2.83	2.50	**2.83**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat163	Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components	Mei Li (Ford Motor Company)	6-31	3.00	3.20	3.40	2.90	**3.14**
mat164	Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials	Michael Tonks (University of Florida)	6-35	3.40	3.10	3.30	2.90	**3.18**
mat173	Self-Sensing Fiber-Reinforced Composites	Christopher Bowland (ORNL)	6-39	3.33	3.33	3.17	3.50	**3.33**
mat174	Carbon-Fiber Technology Facility (CFTF)	Merlin Theodore (ORNL)	6-42	3.25	3.00	3.00	3.25	**3.09**
mat183	High-Temperature Coatings for Valve Alloys	Sebastien Dryepondt (ORNL)	6-44	3.50	3.50	3.25	3.25	**3.44**
mat184	Development of Cast, Higher Temperature Austenitic Alloys	Yuki Yamamoto (ORNL)	6-48	3.25	3.38	3.25	3.38	**3.33**
mat185	Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing	Derek Splitter (ORNL)	6-52	3.70	3.60	3.50	3.60	**3.61**
mat186	Modeling of Light-Duty Engines	Charles Finney (ORNL)	6-56	3.50	3.63	3.75	3.25	**3.56**
mat187	Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys	Dongwon Shin (ORNL)	6-59	3.50	3.63	3.13	3.50	**3.52**
mat188	Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys	Amit Shyam (ORNL)	6-63	3.38	3.38	3.50	3.25	**3.38**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat189	Fundamental Development of Aluminum Alloys for Additive Manufacturing	Alex Plotkowski (ORNL)	6-66	3.25	3.50	3.38	3.00	**3.36**
mat190	Oxidation Resistant Valve Alloys	G. Muralidharan (ORNL)	6-70	3.33	3.33	3.33	3.33	**3.33**
mat191	Overview of Advanced Characterization within the Powertrain Materials Core Program	Tom Watkins (ORNL)	6-73	3.63	3.50	3.63	3.50	**3.55**
mat192	Fundamentals of Austenitic Alloys via Additive Manufacturing	Sebastien Dryepondt (ORNL)	6-77	3.63	3.75	3.38	3.38	**3.63**
mat193	Higher Temperature Heavy-Duty Piston Alloys	Dean Pierce (ORNL)	6-80	3.50	3.50	3.00	3.30	**3.41**
mat195	Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks	Brian Knouff (ORNL)	6-84	3.25	3.00	3.25	2.75	**3.06**
mat196	High Temperature Carbon Fiber Carbonization via Electromagnetic Power	Felix Paulauskas (ORNL)	6-87	3.25	2.88	3.13	3.25	**3.05**
mat197	Multi-Functional Smart Structures for Smart Vehicles	Patrick Blanchard (Ford Motor Company)	6-91	3.00	3.33	3.00	2.83	**3.15**
mat198	Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure	Venkat Aitharaju (General Motors, LLC)	6-93	3.00	3.00	3.50	3.00	**3.06**
mat199	Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project)	Kevin Simmons (PNNL)	6-97	3.40	3.20	3.20	3.00	**3.23**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat200	Additive Manufacturing for Property Optimization for Automotive Applications	Seokpum Kim (ORNL)	6-100	3.50	3.17	3.00	3.17	**3.23**
mat201	Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage	James Lewicki (LLNL)	6-103	2.83	2.83	3.17	2.83	**2.88**
mat202	3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles	Rigoberto Advincula (ORNL)	6-106	3.50	3.50	3.50	3.50	**3.50**
mat203	Low-Cost, High-Throughput Carbon Fiber with Large Diameter	Felix Paulauskas (ORNL)	6-108	3.38	3.00	3.13	3.38	**3.16**
mat204	New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry	Tomonori Saito (ORNL)	6-112	3.00	3.00	2.17	3.00	**2.90**
mat205	Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites	Amit Naskar (ORNL)	6-116	3.33	3.00	3.00	3.17	**3.10**
mat206	Soft Smart Tools Using Additive Manufacturing	Jay Gaillard (SRNL)	6-118	2.63	3.00	3.13	2.63	**2.88**
mat207	Multi-Material, Functional Composites with Hierarchical Structures	Christopher Bowland (ORNL)	6-123	3.25	3.25	3.00	3.00	**3.19**
mat208	Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste	Lelia Cosimbescu (PNNL)	6-126	3.50	3.33	2.50	3.33	**3.27**
mat209	Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling	Gregg Beckham (NREL)	6-129	3.50	3.63	2.88	3.38	**3.47**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat210	A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite	Patrick Blanchard (Ford Motor Company)	6-133	3.50	3.75	3.50	3.50	**3.63**
mat211	Self-Sensing Self-Sustaining Carbon Fiber-Reinforced Polymer (S4CFRP) Composites for Next-Generation Vehicles	Masato Mizuta (Newport Sensors, Inc.)	6-135	3.10	3.00	2.70	3.00	**2.99**
mat212	Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles	Amrita Kumar (Acellent Technologies, Inc.)	6-140	3.50	3.38	3.50	3.50	**3.44**
mat213	Active Monitoring of Composite Structures through Embedded Synthetic Fiber Sensor	Halina Tran (Intellisense Systems Inc.)	6-144	3.25	3.38	3.38	3.17	**3.32**
mat214	Multifunctional Composites for Vehicles	Henry Sodano (Trimer Technologies, LLC)	6-148	3.63	3.50	2.88	3.33	**3.43**
mat215	Short Fiber Preform Technology for Automotive Part Production - Phase II	Dirk Heider (Composites Automation, LLC)	6-152	3.50	3.50	3.17	3.33	**3.44**
mat216	Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites - Phase II	Henry Sodano (Trimer Technologies, LLC)	6-154	3.33	3.67	2.67	3.00	**3.38**
mat217	New Higher Temperature Performance Alloys (1A2)	Amit Shyam (ORNL)	6-157	3.50	3.67	3.50	3.33	**3.56**
mat218	Selective Material Processing to Improve Local Properties (2B2)	Glenn Grant (PNNL)	6-160	3.50	3.33	3.33	3.17	**3.35**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat219	Fundamentals of Non-Equilibrium Processing	Ying Yang (ORNL)	6-163	3.20	3.30	3.30	3.00	**3.24**
mat220	Ferritic Alloys for Heavy-Duty Pistons via Additive Manufacturing (3B2)	Peeyush Nandwana (ORNL)	6-168	3.40	3.60	3.30	3.50	**3.50**
mat221	Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials	Dean Pierce (ORNL/ Cummins)	6-172	3.75	3.50	3.63	3.63	**3.59**
mat222	Extending Ultrasonic Welding Techniques to New Material Pairs	Jian Chen (ORNL)	6-175	2.80	3.10	3.00	2.70	**2.96**
mat223	Extending High Rate Riveting to New Material Pairs	Kevin Simmons (PNNL)	6-178	3.25	3.25	3.25	3.25	**3.25**
mat224	Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness	Piyush Upahdyay (PNNL/ORNL)	6-182	3.38	3.50	3.38	3.00	**3.39**
mat225	Surface Modifications for Improved Joining and Corrosion Resistance	Mike Brady (ORNL/PNNL)	6-185	3.30	3.20	3.00	3.20	**3.20**
mat226	Machine Learning for Joint Quality and Control	Keerti Kappagantula (ORNL/PNNL)	6-189	3.50	3.40	3.60	3.40	**3.45**
mat227	Prediction of Aluminum/Steel Joint Failure	Chris Smith (PNNL/ General Motors Company)	6-193	3.13	3.00	3.50	2.75	**3.06**
mat228	New Technologies for High-Performance Lightweight Aluminum Castings	Paul Jablonski (NETL/ General Motors Company)	6-196	3.00	3.00	3.20	3.20	**3.05**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat229	Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components	Govindarajan Muralidharan (ORNL/FCA LLC)	6-200	3.13	3.13	3.38	3.13	**3.16**
mat230	Laser Powder Bed Fusion Parameter Development for Novel Steel and Aluminum Powders Using In Situ Synchrotron Imaging and Diffraction	Aaron Greco (ANL/General Motors Company)	6-204	3.00	3.00	3.25	3.13	**3.05**
mat232	Light Metals Core Program - Thrust 1 – Selective Processing of Al Sheet	Darrell Herling (PNNL)	6-207	3.25	3.25	3.00	3.25	**3.22**
mat233	Light Metals Core Program - Thrust 2 – Selective Processing of Al Castings	Glenn Grant (PNNL)	6-211	2.63	2.88	2.75	3.00	**2.81**
mat234	Light Metals Core Program - Thrust 3 – Selective Processing of Mg Castings	Vineet Joshi (PNNL)	6-214	3.50	3.50	3.38	3.25	**3.45**
mat235	Light Metals Core Program - Thrust 4 - Characterization, Modeling and Lifecycle	Arun Devaraj (PNNL)	6-217	3.13	2.88	3.00	3.00	**2.97**
Overall Average				**3.28**	**3.29**	**3.22**	**3.16**	**3.26**

Presentation Number: mat146
Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites
Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory/Ames Laboratory)

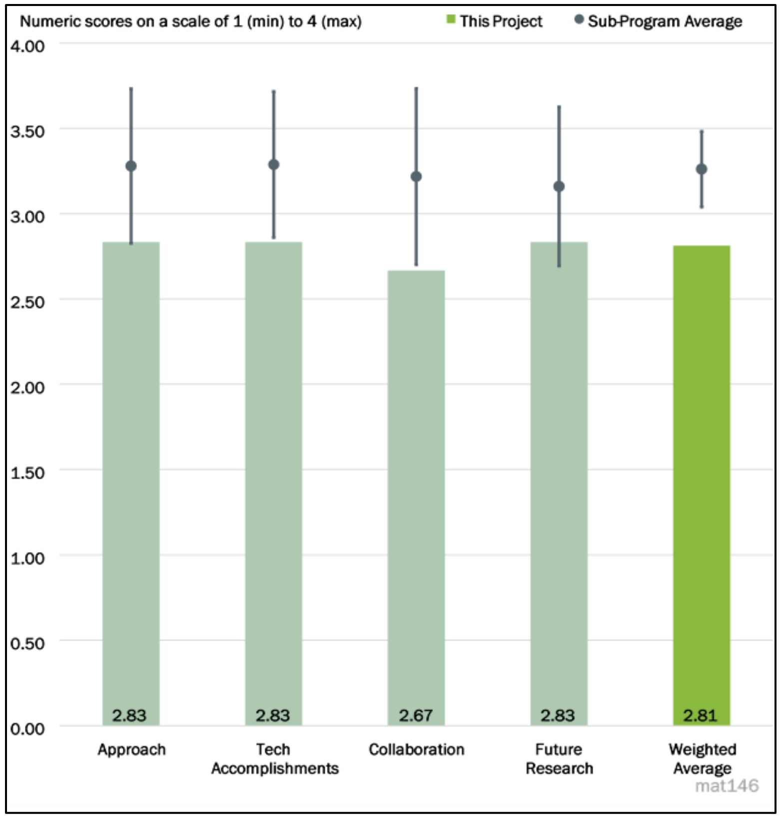

Figure 6-1 - Presentation Number: mat146 Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory/Ames Laboratory)

Presenter

Vlastimil Kunc, Oak Ridge National Laboratory/Ames Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed a novel approach relative to the current state of the art (SOA) that increases speed. The project focused on stiffness and dampening, but there are limited data or information on strength, fiber length effects, fiber orientation, and fiber volume fraction effects on strength.

Reviewer 2:

The reviewer noted that the technical barrier addressed on the Overview slide is “Barrier: Use of lower-density materials with suitable mechanical properties, i.e., materials with higher strength-to-weight and/or higher stiffness-to-weight ratios.[1]” with reference one being the “U.S. DRIVE MTT Roadmap, section 4.” The text in section four of that referenced document lists “use of lower-density materials with suitable mechanical properties, i.e., materials with higher strength-to-weight and/or higher stiffness-to-weight ratios” as an element of traditional, historic approaches to reduction of vehicle weight. The reviewer commented that weight reduction is the goal of the issues and challenges identified in that Roadmap, but the work of MAT146 addresses none of the five Critical Challenges Identified for Carbon Fiber (CF) composites: low-cost, high-volume manufacturing; low-cost fibers; predictive modeling; joining, non-destructive evaluation (NDE), life monitoring, and repair; and recycling. The current project impressively advances new concepts for high strength-to-weight and stiffness-to-weight materials, but the technical barrier identified that the project approach addressed is not one of the prioritized barriers listed in the referenced source. Additionally, the reviewer stated that the approach does not address one of the five critical challenges mentioned therein.

Reviewer 3:

The reviewer stated that the systematic approach of mixing Voigt and Reuss layering mechanisms to produce the tunable stiffness and damping is a solid one to overcoming the barriers. The efforts on the print heads for improving extrusion speed and robustness are the next step being addressed in the next budget period. However, the reviewer questioned the project management scheme, given the milestones appear to have been modified from the 2020 Annual Merit Review (AMR) list.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the project has done a great job in developing new processes, designing structures for efficiency, and developing materials.

Reviewer 2:

The reviewer reported that examples are provided on the significant improvement in capabilities established and properties measured in the current status of the work compared to the status at an earlier point in the project.

Projection design and lighter weight optics are apparently enabling faster exposure and scanning, though it was unclear to the reviewer what the status was before and after these improvements (i.e., how much faster?).

This reviewer observed that the transition from a truss-lattice geometry to a plate-lattice geometry resulted in improved normalized stiffness versus relative density. An increase in volume fraction of the bi-material plate-lattice soft phase resulted in significant improvement in absorbed energy. The use of bi-material rather than CF-only plate lattices led to significantly higher normalized absorbed energy with some reduction in normalized peak strength.

The stated overall objective of the work is the creation of materials that are ultralight, strong, and tough. The reviewer asserted that definite progress is being made in design and demonstration of ultralight geometries with strong specific weight and specific toughness. What is not clear is the strength and toughness of the demonstrated materials, not only relative to other materials normalized by density, but relative to material performance requirements of components in commercial vehicles. What is a target application on a vehicle of the materials being developed? What are the strength and stiffness requirements of a material used in that application? If the bi-material cubic+octet plate-lattice is envisioned to replace and thereby reduce the mass of a current structural member or foam or panel fill, what are the strength and/or stiffness performance requirements that drive material selections for the envisioned application and how close is the current performance of the material in development to that requirement? The reviewer commented that future work includes developing the ability to control CF alignment and orientation. How is performance of the printed structures with achieved alignment and orientation anticipated to compare with that of current materials?

Reviewer 3:

This reviewer observed solid progress on the technical accomplishments in the last year. Printing a 200 millimeter (mm) × 200 mm × 100 mm lattice structure in under 4 hours is a good start, but far below required production targets. The reviewer questioned how the project milestones have morphed from the 2020 AMR presentation to those listed in this year’s 2021 AMR presentation. This changing project management structure with different milestones in different presentations made the reviewer question what the project team is really doing and whether it is aligned for success.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The described work includes strengths of both the University of California at Los Angeles (UCLA) group and the Oak Ridge National Laboratory (ORNL) group. At least one publication includes co-authors from both partners. It was not apparent to the reviewer from the slides which elements of the described work were performed by which partner institution.

Reviewer 2:

It was not clear to the reviewer from the presentation the contributions by the team collaborators. It would enhance the presentation to clearly delineate who did what work to give some indication of the team participation and contributions to the overall project.

Reviewer 3:

While the progress suggests good cooperation, there is nothing in the AMR presentation that defines the roles and responsibilities of the partners, the typical interaction timing, or the project management tracking scheme. It was not clear to the reviewer what is being done at ORNL and what UCLA is contributing. How often do the project teams meet and exchange project information?

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future work was logical to the reviewer and addresses some of the concerns that should be focused on, such as rheological behavior, fiber orientation, and fiber length distribution.

Reviewer 2:

The proposed work for the next year addresses the next most pressing project needs. The extrusion of the carbon fiber reinforced polymer (CFRP) and the size and speed of producing design artifacts and the integration of multi-materials for tailored stiffness and damping all need to be addressed, according to the reviewer.

Reviewer 3:

The reviewer stated that the go/no-go milestone targets a micro-lattice with a density of less than 500 kilograms per square meter (kg/m^3) and specific strength greater than 1 kilopascal ($kPa)/(kg/m^3$). This target density is very low compared to the 1,500–2,000 kg/m^3 of CF and epoxy or glass fiber (GF) and polyester composites. The target strength is normalized by the density: $1\ kPa/(kg/m^3) \times 500\ kg/m^3 = 500\ kPa$. This is equivalent to the compressive strength of expanded polystyrene insulation foam. What strength is required for use of the developed material in vehicle lightweighting? What is the potential or anticipated vehicle weight savings or market penetration for the production cost of the considered material?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the design and materials could reduce the weight of vehicles if the material performance is achieved.

Reviewer 2:

This project addresses the need for lower cost, higher energy absorbing printed structures. The reviewer asserted that the focus on multi-material and extruded CFRP is a high risk and high reward project.

Reviewer 3:

This project seeks to develop and demonstrate novel geometries, compositions, and the manufacturing methods to produce ultra-low density, high specific strength, and high specific toughness materials. These aims support vehicle mass reduction and weight reduction. Notably, the U.S. Department of Energy (DOE) objectives target mass reduction at equal affordability ("50% mass reduction at equal affordability" [stretch objective long term]); cost-based weight reduction ("U.S. DRIVE Target 2025* – 25% weight reduction (Glider) < $5/lb"); and weight reduction at equal performance relative to currently relied upon materials ("Equal performance (Crash, NVH, Durability, Reliability & Recyclability)").

According to the reviewer, a challenge for the current project approaches will be identifying a path to weight reduction that is "high volume" and meets DOE affordability and cost premium targets. Also, the goal of density reduction at equal performance will need to be met, requiring competitive absolute strength and toughness performance apart from specific strength and toughness, and acknowledging that lighter parts might have lower performance requirements to support themselves.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Project funds appear to have 50% expended. Based on progress to date, the reviewer said that the remaining funds should be sufficient to address some of the identified future work targets of improved fiber alignment, increased print speed, increased print area, and increased material inclusion flexibility.

Reviewer 2:

The reviewer found that the project is adequately funded, and the project team has done a good job of dealing with project impacts due to coronavirus disease 2019 (COVID-19).

Reviewer 3:

The funding level is sufficient for the project goals. The reviewer had concerns over the tracking and use of the budget, given the shifting milestones.

Presentation Number: mat149
Presentation Title: Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory/Lawrence Berkeley National Laboratory)

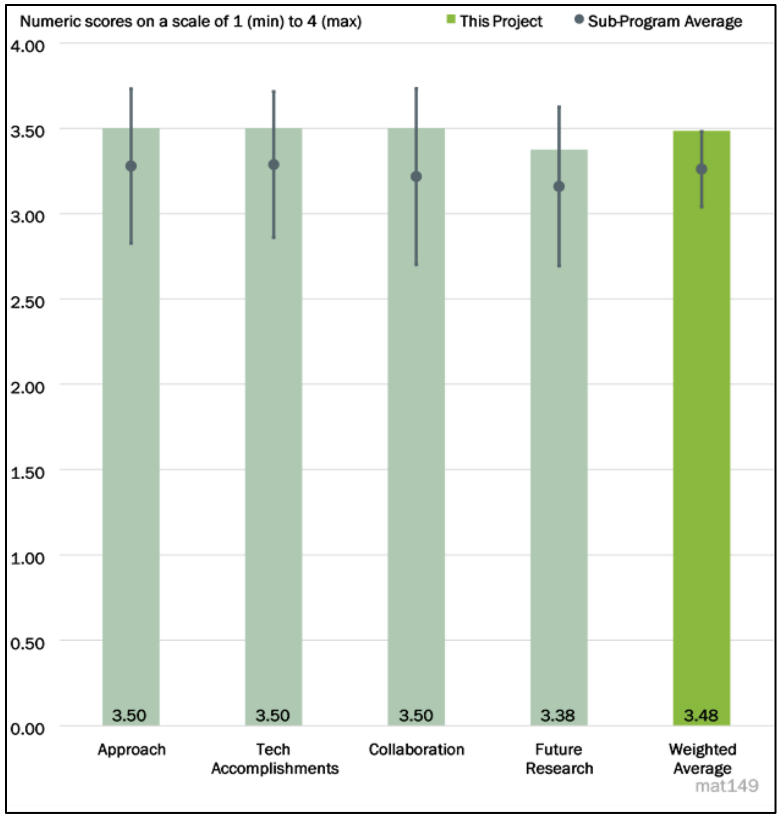

Figure 6-2 - Presentation Number: mat149 Presentation Title: Shear Assisted Processing and Extrusion (ShAPE) of Lightweight Alloys for Automotive Components Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory/Lawrence Berkeley National Laboratory)

Presenter

Scott Whalen, Pacific Northwest National Laboratory/Lawrence Berkeley National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer observed an excellent approach to systematically attacking the barriers to magnesium (Mg) extrusions and reducing the cost of aluminum (Al) extrusions.

Reviewer 2:

Benefits for utilization of Al and Mg with Shear-Assisted Processing and Extrusion (ShAPE™) processing was outlined clearly. The researcher explained the approach well and followed up with responses to the requests made by the reviewer.

Reviewer 3:

The project is strong and addresses some important areas for extrusion improvement. The emphasis on using a secondary alloy is important; however, the project could address more on chemistry sensitivity (as part of using cast billet as feedstock). It would also be useful to have some targets for extrusion speed improvement better defined when compared to the conventional process. Textures, microstructure uniformity, and the ability of the process to hold to dimensional tolerances are also important considerations, and those measurements would make project objectives stronger. It was unclear to the reviewer if those are part of the future work.

Reviewer 4:

The reviewer said that the project is exploring the viability of the ShAPE process for light metals. The plan for experiments for A6063 and ZK60 is good; all parameters that affect the process, including temperatures, speed, and ingot quality, are being assessed. Also, the influence of the process on properties in as-fabricated and heat-treated conditions is being evaluated.

A new tool for port hole extrusion is being designed to explore the potential for multi-wall thickness. The reviewer noted that all these efforts are well supported by the industrial partner.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer reported that progress on all three critical areas—Mg ZK60, Al 6061 from scrap turned into briquets, and the starting efforts on a porthole extrusion—is impressive.

Reviewer 2:

The project seems to have accomplished quite a bit on producing extrusions. Porthole die results will be interesting. The reviewer said that it is good that there is engagement with the die maker.

Reviewer 3:

The reviewer stated that experiments demonstrated that the process is viable for extruding both Al and Mg alloys. Both extrusion speeds and quality of Al alloys appear to be closer to normal operation, making it acceptable for use. Use of recycled scrap material seems to make the process attractive from a sustainability perspective. It also provides an economic incentive for recycling of machining chips.

One of the major advantages cited for Mg extrusion is the lack of orientation developed due to high shear rates. This aspect does not seem to provide any improvements in the symmetry. Also, the reviewer asserted that the speed required to have an economic advantage in the case of Mg is yet to be achieved.

Reviewer 4:

With ShAPE processing, the reviewer reported that T6 properties were achieved with a T5 temper for several extrusion speeds and process temperatures. With the new process, energy can be saved and the cost of solutionizing is eliminated. The team is aware that eliminating the solution treatment can lead to heterogeneity in properties.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is excellent collaboration between the industry partner and a national laboratory in this Lightweight Materials Consortium (LightMAT) project. The research license for ShAPE from Magna was encouraging to the reviewer.

Reviewer 2:

The project team seemed well aligned and complete to the reviewer.

Reviewer 3:

The reviewer noted that industrial partner, Magna, is fully integrated in the project. With the supply of raw materials (including consolidated chip billets) and the design of tools, the reviewer found that Magna has contributed significantly to the project. However, the full supply chain is not involved in the project; most probably, Magna is pursuing separate supply chain development. However, in this situation, all members of the supply chain can contribute to resolving many roadblocks that may arise later. The process is being promoted as an economic success with the use of recycled chips. The reviewer indicated that the following should be present, at least in advancing capacity: characterization of chips (machining firms); preparation of billets; tool designers; and extruders.

Reviewer 4:

The accomplishments show how the team must be working together. The reviewer would have liked to see a chart or table with the typical interactions (i.e., weekly, monthly, and/or quarterly) and a clear list of roles and responsibilities plus a "gives and gets" table showing the interactions between the partners and the major vendors as the porthole die is developed.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the proposed work addresses the remaining major barriers. The team has an excellent plan.

Reviewer 2:

The proposed plan seemed logical and well thought out to the reviewer. It would be good to make sure there are more metrics assigned as targets on the manufacturability of the porthole bridge die tooling, such as extrusion speed, dimensional accuracy, surface quality, etc.

Reviewer 3:

The reviewer commented that plans for the future take advantage of progress made in the current fiscal year (FY).

Reviewer 4:

The plan is to complete the circular and non-circular tube extrusions using both Al and Mg alloys. The reviewer noted that there is no plan for modeling of the process of using chips for extrusion. This could help improve the process. Also, modeling can help to optimize the extrusion speed for magnesium alloys.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that reducing the energy use for transportation is one of the prime objectives of DOE. Developing a recycling process for chips will contribute to sustainability and reduced energy use.

Reviewer 2:

This project supports lightweighting efforts for the glider with a novel extrusion technology. The reviewer stated that it also incorporates the use of secondary feedstock to reduce the carbon footprint.

Reviewer 3:

Both from a Mg replacement of Al (i.e., weight reduction) and scrap reuse point of view, the reviewer remarked that this project supports DOE objectives.

Reviewer 4:

Mg and Al lightweighting helps to improve fuel economy and extend electric vehicle (EV) range. The use of 100% recycled Al scrap is a huge cost and greenhouse gas (GHG) savings for OEMs. The reviewer opined that developing a procedure for both Al scrap and Mg to be effectively extruded with a porthole closed section and ideally a multi-cell closed section is critical to adoption in the automotive sector.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The funding seemed sufficient to the reviewer to complete this work. The supplier partners appear to be very engaged and have made significant in-kind contributions.

Reviewer 2:

Resources are sufficient, according to the reviewer.

Reviewer 3:

The reviewer found no plans for modeling; if modeling is included, then additional resources can be justified.

Reviewer 4:

The reviewer opined that resources might be a bit shy to develop a porthole extrusion die and procedure.

Presentation Number: mat151
Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints
Principal Investigator: Adam Powell (Worcester Polytechnic Institute/Los Alamos National Laboratory)

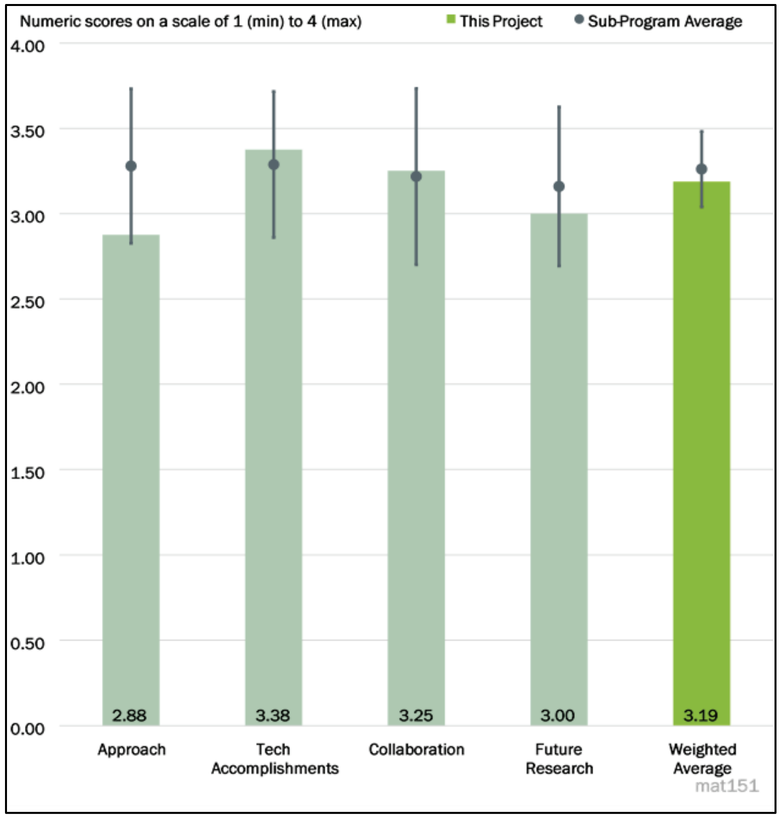

Figure 6-3 - Presentation Number: mat151 Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints Principal Investigator: Adam Powell (Worcester Polytechnic Institute/Los Alamos National Laboratory)

Presenter

Adam Powell, Worcester Polytechnic Institute/ Los Alamos National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The main barrier addressed in this work is the limited understanding of Mg-Al joint corrosion and fracture, and the technical approach is well focused on the critical barriers. The combination of modeling and experimental work is excellent. In the remaining approximately one-third of the project, the reviewer suggested that the team will need to focus on integrating the many different experimental findings into a cohesive model.

Reviewer 2:

Validation of the corrosion model on the Mg pitting was a good approach to then investigating the general corrosion of the joint leading to mechanical property degradation. Intermetallics of Mg-Al were cited as a major difference in friction-stir welding (FSW) compared to Mg-iron (Fe), yet the reviewer did not see any work to incorporate these particles in the corrosion model. Also, despite the 5-week salt spray testing being a standard, it was not clear to the reviewer that this level of testing created measurable mechanical property degradation. Also, how the mechanical property degradation caused by corrosion will be calculated is not clear.

Reviewer 3:

The presenter outlined the project approach through milestones. The reviewer was not sure what the basis was for the go/no-go milestones. What is the significance of predicting corrosion pit depth within plus or minus (±) 2x, and how does it relate to predicting corroded joint strength or fatigue strength within ±10%?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent work in identifying the supremacy of the triangular tool for the Al-Mg material combination. The reviewer asserted that timing may be a bit tight in completing the corrosion exposure and measuring the mechanical property degradation as validation of the corrosion and mechanical property degradation simulations.

Reviewer 2:

The reviewer found that good progress is being made across multiple aspects of the project, with some very promising work underway in the experimental investigation of the “swirl” regions using multiple techniques. The nanoindentation study to investigate spatial variations of mechanical properties within the swirl was particularly clever. It will be interesting to see how the team leverages the new nanohardness map and phase map data to improve the mechanics model. Also, the team seems to have been successful in adapting their FSW technique for welding from hard-to-soft as needed for the challenge problem application (opposite of soft-to-hard convention).

There is no explicit mention of whether the first go/no-go milestone (i.e., prediction of pit depth) was achieved; possibly, it was not achieved (based on the comment that the modeled pitting rate was faster than observed). Because that is the only milestone past its planned completion date, it was difficult for the reviewer to assess whether the project plan is on schedule or not.

Reviewer 3:

The phase-field galvanic corrosion oxidation model predicts experimental data. The reviewer observed that the team completed a validated model that predicts corrosion and mechanical failure.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaborators appeared to the reviewer to be well coordinated and effective, with each participant making valuable contributions and delivering results.

Reviewer 2:

The reviewer asserted that there is great teamwork involving national laboratories, an industrial manufacturer, and a university.

Reviewer 3:

The reviewer found good use of ORNL microscopy of weld sections to highlight challenges in creating constitutive models for mechanics performance simulation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The future work plan seems appropriate, though perhaps a bit open ended. For example, one idea for future work is to “understand fracture based on nanohardness maps.” More specifics on how the team might accomplish this would be useful. Future work plans do not explicitly include a study of grain size effects as suggested by reviewers both this year and last. In a verbal response to a reviewer question, it was suggested to possibly use small angle neutron scattering to investigate grain size further. The reviewer hoped that the team will consider integrating this into future work if the budget and time allow.

Reviewer 2:

The reviewer felt that it is correct to understand the differences in fracture mode of the Al-Mg versus the prior Mg-Fe fracture where the model was validated. Referencing Slides 10 and 12, the reviewer explained that nanohardness stratification is certainly one aspect, but a macro difference is that with the Mg-Al fracture, there is only a single hook whereas the Mg-Fe exhibited two, i.e., on both sides.

Reviewer 3:

The team plans to modify the models, particularly the electrochemical and mechanical models. The reviewer observed that the team also plans to correlate performance during cyclic loading.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form and in the right application, it is imperative to achieve dissimilar material joints. Knowledge of corrosion on mechanical performance is necessary to implement such dissimilar material joints.

Reviewer 2:

According to the reviewer, this project is well aligned with DOE objectives in multi-material joining capability and joint corrosion performance.

Reviewer 3:

High volume manufacturing of corrosion resistant joints for vehicles is needed. Also, the reviewer opined that predicting their performance is critical.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The team has a variety of experimental equipment at its disposal and has been able to shift to new techniques as needed and without running into resource limitations. As for the monetary resources, they appeared to the reviewer to be on pace.

Reviewer 2:

The reviewer noted that resource allocation is adequate.

Reviewer 3:

The reviewer observed that 71% of the DOE funding has already been spent. The project states that a weak coupling exists between the corrosion and mechanical performance. The remaining 29% of the budget may make it difficult to investigate the nature of this gap and potential solutions.

Presentation Number: mat152
Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives
Principal Investigator: Roozbeh Dargazany (Michigan State University/National Renewable Energy Laboratory)

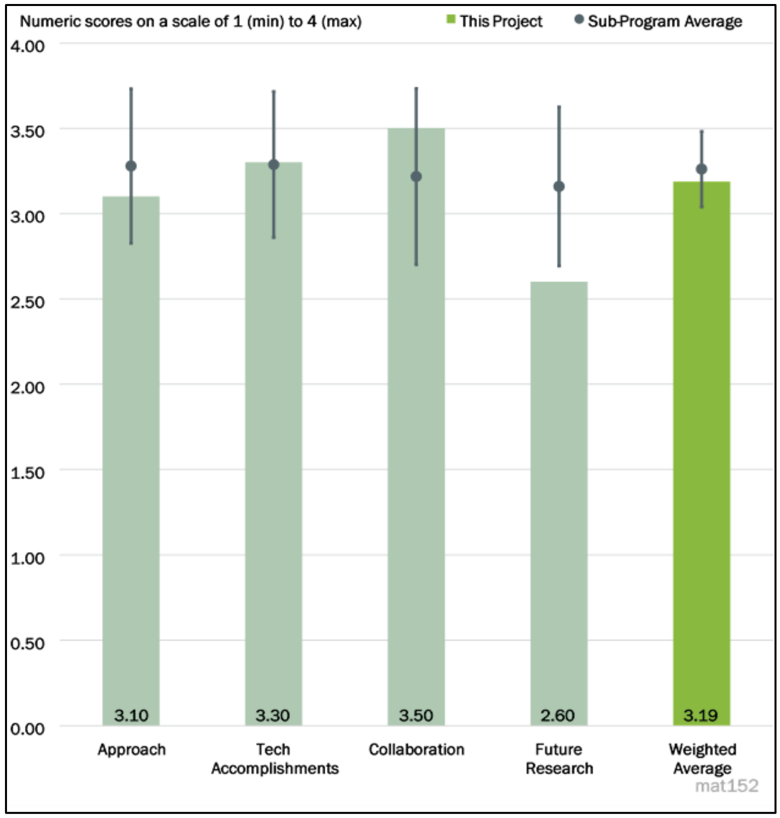

Figure 6-4 - Presentation Number: mat152 Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives Principal Investigator: Roozbeh Dargazany (Michigan State University/National Renewable Energy Laboratory)

Presenter

Roozbeh Dargazany, Michigan State University/National Renewable Energy Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach presented for the overall project is very detailed with well-defined areas of development and their respective performers identified over the entire project timeline. Each task area and the respective subtasks are designed to address all the technical barriers that are identified early in the presentation. The approach is coupled with the milestones for each fiscal year and specifics for each subtask that is either completed or in progress. A second slide presented the approach for modeling, which is broken down into four areas associated with separate damage mechanisms. The modeling approach is also well designed and progresses from data requirements to mechanical analyses, to neural network design and validation, to software development, and to prediction of the various failure modes. With both a well-designed project approach and a well-designed modeling approach, this physics-based, the reviewer asserted that this data-driven effort to model damage accumulation caused by corrosive effects is completely feasible.

Reviewer 2:

The reviewer said that the test plan was clearly defined and executed.

Reviewer 3:

The team is developing a theoretical constitutive model for various adhesives. The researchers have considered various damage mechanisms including mechanical deformation-induced decay in performance as well as chemical degradation-induced deterioration of adhesive performance. The project team has studied all probable degradation, including hydrothermal, thermal, hygrothermal, photooxidation, etc. The reviewer was not sure if all these degradation models are common for all adhesives. Therefore, a key question remains: how would those models be integrated into a generalized platform?

Reviewer 4:

The reviewer stated that the project only focuses on adhesives without considering the material substrates, which may very well affect the behavior and aging of the adhesives.

The project focuses only on acrylic, polyurethane, and silicone adhesives instead of epoxies, which are much more widely used in automotive structures due to the higher modulus. Because the project does not include epoxies, then the reviewer opined that it is not helpful in a vast majority of potential lightweight and multi-material structural joining applications.

It is not clear how this project will speed up the design of composite joints and/or reduce the time and cost required for testing corrosion failure. Also, it was not clear to the reviewer how the results of this project are to be used by the automotive industry. What input is required? What output is expected?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The presenter had too many slides (54 for the presentation and 16 backup slides for a total of 70 slides) to cover all of the technical accomplishments and progress in the twenty minutes allowed and was cut short by the AMR facilitator. Because of this, only the first 16 slides were presented. The technical accomplishments presented (and a review of those not presented) demonstrate several outstanding accomplishments in this project for modeling damage in adhesives caused by effects of corrosion. When the progress is measured against the milestones and performance indicators, the reviewer praised the project manager as having done an outstanding job of conducting research that addresses the technical barriers identified earlier in the presentation.

Reviewer 2:

According to the reviewer, the team made significant progress in analyzing various degradation models and associated validation of the models by use of experimental data.

Reviewer 3:

Substantial technical accomplishments indicated good progress to the reviewer.

Reviewer 4:

Good progress has been made toward achieving the overall project goal. It was not clear to the reviewer as to the contribution of individual participants.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is an outstanding team for collaboration on this project, which includes a university (for early-stage research and modeling) with two facilities for database and modeling and for materials characterization and testing. It also includes a supplier of commercial software, a supplier of the joining technology to be used, a company in the chemicals industry, and a lightweight materials consultant. This team exemplifies elements needed for acceptance of a joining technology and predictive models for the end-user. Close coordination during the planning phase for this diverse yet coordinated team was apparent to the reviewer.

Reviewer 2:

Overall, the project results to date indicate that the large group of dissimilar collaborators are to be working in a well-coordinated manner. It was not clear who the auto industry joining expert is and how the expert's guidance is being implemented.

Reviewer 3:

The reviewer observed an excellent team involving multiple industries and experts from other industries on advisory roles. However, it was not clear to the reviewer who is doing what. The approach and milestone chart shows involvement of entities, but it does not list the High Performance Material Group (HPM). Perhaps HPM is involved in all the tasks. Also, it is unclear which entity is responsible for what milestone.

Reviewer 4:

The contribution of individual participants was not clear to this reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Future research is described in three brief bullet points. The reviewer asserted that degradation of adhesion properties should have been already studied based on the models for chemical degradation-induced decay in performance of the adhesives.

Reviewer 2:

The presenter did not offer any future research, which is described on Slide 53. The reviewer said that the work described is a continuation of the current modeling effort to perform more material characterization experiments and determination of other effects causing degradation of adhesion for joining materials. A statement is also made regarding validation of multi-agent simulators and the development of methods to minimize the data needed for training the models. This is a logical progression of further work that is needed to increase the understanding and model the effects of damage accumulation on adhesive materials.

Reviewer 3:

According to the reviewer, the proposed future research does not identify any plans to evaluate adhesives with lightweight material substrates. The proposed future research does not specify how this work will be made useful to auto industry users.

Reviewer 4:

The reviewer remarked that the discussion did not include a description of the remaining tasks.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer indicated that this project directly supports the overall DOE VTO technical targets and United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE) partnership (includes DOE) roadmap goals and high priority research needs for multi-material joining and predictive modeling for dissimilar material joining.

Reviewer 2:

The reviewer opined that designing adhesive joints will be effective if there is a model that can predict the adhesive performance. DOE has a very ambitious goal; therefore, this project is highly relevant.

Reviewer 3:

The reviewer commented that the research did not include application of the predictive model relative to real-world joining of dissimilar materials.

Reviewer 4:

It was difficult for the reviewer to see how a project focusing only on adhesives with no material substrates being considered and no validation with industry type tests will be useful to industry. The project does not appear to be focusing on the types of adhesives most widely used in the auto industry to enable lighter weight structures. None of the work seems to be well defined for improving reliability of joining of dissimilar joints. In fact, the project report does not even mention substrate materials anywhere (e.g., Al, steel, Mg, polymer composites, etc.).

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Significant progress has been made with the available resources. The project appeared to the reviewer to be within budget constraints.

Reviewer 2:

The reviewer observed that the DOE investment is about $333,000 per year average, which is sufficient to achieve the stated milestones within the 3-year performance period. The majority of the work is modeling, so the physical resources needed are minimal. The collaboration partners are well chosen and sufficient to perform the material testing and model validation.

Reviewer 3:

The reviewer said that the team has adequate resources.

Reviewer 4:

Although the relevance of the work is not well defined, the resources seemed sufficient to the reviewer to conduct the type of work that is being performed.

Presentation Number: mat153
Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints
Principal Investigator: Miki Banu (University of Michigan/Oak Ridge National Laboratory)

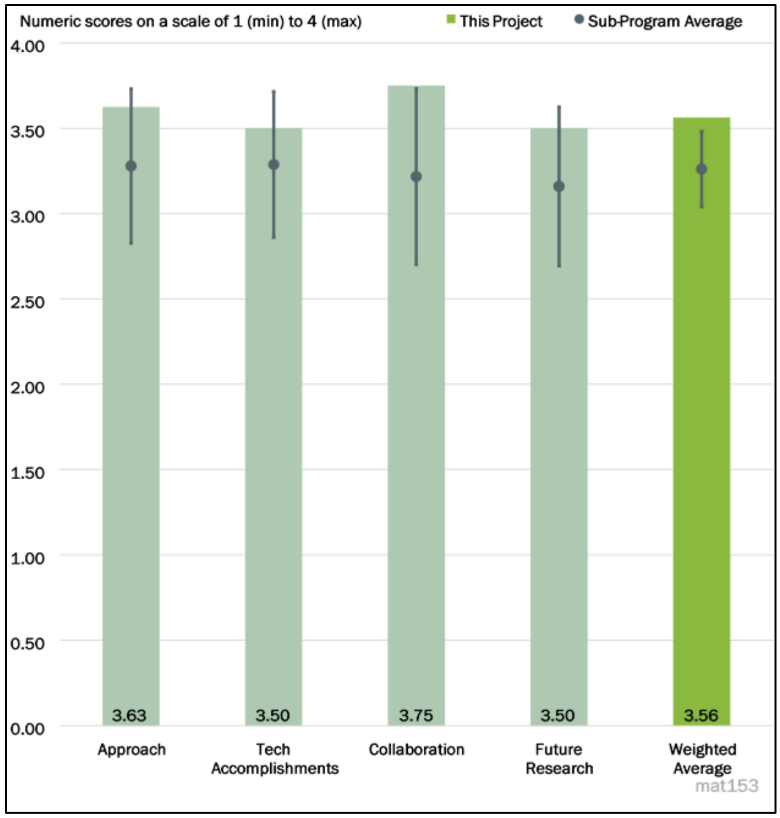

Figure 6-5 - Presentation Number: mat153 Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints Principal Investigator: Miki Banu (University of Michigan/Oak Ridge National Laboratory)

Presenter

Miki Banu, University of Michigan/ Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team aims at developing multiscale models for predicting corrosion rates and their impact on joining performance of Al and of steel based on structure property performance interaction at different scales. The team considered resistive spot welding, riveting, and rivet welding. Joining and subsequent corrosion at the Al and steel interface lead to formation of intermetallic compounds and deterioration in mechanical deformation behavior. Grain-level phase field modeling delivers prediction of corrosion sites, corrosion rates, and mechanical performance of the homogenized mechanical response. Integration of atomic level and grain-level modeling will deliver performance prediction. The reviewer praised the approach outlined and presented as excellent.

Reviewer 2:

This is a well-designed and executed experiment with a very good correlation of results. The reviewer indicated that significant involvement of original equipment manufacturers (OEMs) ensures correct test methods for the targeted application.

Reviewer 3:

The project seemed to the reviewer to be well planned, well coordinated, and focused on the final goals.

Reviewer 4:

Evaluation of three different joining methods enables better understanding and evaluation of model predictive capability and robustness. However, considering the size of the budget for this project, it seemed to the reviewer that more joint types and material combinations could be evaluated.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The presentation indicates good accomplishments for this project to date. The reviewer was particularly impressed with the team's decision to take advantage of the imposed 2-month shutdown of the General Motors (GM) corrosion chamber to evaluate the real-world occurrence of breaks in corrosion exposure.

Reviewer 2:

It appears that a lot of good work is being done here. For example, the experimental work correlating patterns in lap -shear, force-displacement curves to the corrosion exposure time (Slide 9) looked quite interesting to the reviewer, and the force-displacement curve predictions (Slide 15) look promising.

In general, the reviewer wished that the plots and figures had been made a bit bigger and easier to read in the presentation. Quite a few of the results and graphics were tiny and difficult to decipher, even when zooming in. That made it difficult for the reviewer to provide more detailed technical comments.

Reviewer 3:

The reviewer commented that the team has made very good accomplishments.

Reviewer 4:

The project is expected to end by the end of this calendar year. COVID-19 indeed impacted the progress. Still, the reviewer indicated that a lot more examples showing experimental validation of the predicted corrosion failure of the joints would have been good. The good news is that the code would be available for others to test.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This is an excellent team, and the reviewer found that the diverse expertise of the investigators is an asset for this project.

Reviewer 2:

The reviewer appreciated Slide 20, which clearly laid out the specific contributions of each participant to the project. This seems to be an effective collaboration.

Reviewer 3:

According to the reviewer, the project shows good collaboration of academia and industry, and the accomplishments thus far indicate the collaborators are functioning well together.

Reviewer 4:

Discussion did not include who did what, but the reviewer indicated that the results speak for themselves.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Overall, the proposed future work appeared to the reviewer to be well aligned with meeting the project's stated goals. The proposed future work is to formulate guidelines to assist automakers in prediction of corrosion and "end of life" solutions, and proposing solutions for designing new alloys less susceptible to corrosion for use in multi-material assemblies will be very valuable for helping the automotive industry meet DOE's lightweight multi-material glider weight reduction goals.

Reviewer 2:

The project is 80% complete and is wrapping up in December. While the project is progressing on track, there are quite a few milestones still remaining, which the reviewer warned will require a focused effort to complete over the next 6months. It appears that the research team has a sound strategy.

Reviewer 3:

The reviewer noted that the team will make the code available for others and the project data would also be available.

Reviewer 4:

The reviewer found that the future work is well defined.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Corrosion-resistant multi-material joints are essential for automobiles. This project and the overall joining program are highly relevant, according to the reviewer.

Reviewer 2:

Performance degradation over time is a critical component of reliability and performance. The reviewer asserted that models to predict performance of dissimilar materials are needed to efficiently design structures and define useful life.

Reviewer 3:

The reviewer stated that the project focuses on corrosion prediction of dissimilar material joints, which is a key challenge in the development of lightweight multi-material automobile structures.

Reviewer 4:

This project supports DOE objectives around multi-material systems and also aligns with goals to advance multi-scale computation and other Integrated Computational Materials Engineering (ICME) approaches.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the project is well planned and executed, deploying sufficient resources in an efficient manner.

Reviewer 2:

Resources (equipment and monetary) appeared sufficient to the reviewer. The project is progressing on track.

Reviewer 3:

The reviewer remarked that resources are sufficient.

Reviewer 4:

Although it is good that the project is planning to evaluate three unique joining processes for the joining of Al and steel, it seemed to the reviewer that the budget should be sufficient to evaluate (and therefore further validate the models) of more joining processes and material combinations than are planned for this project.

Presentation Number: mat162
Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers felt that the project was relevant to current DOE objectives, 33% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

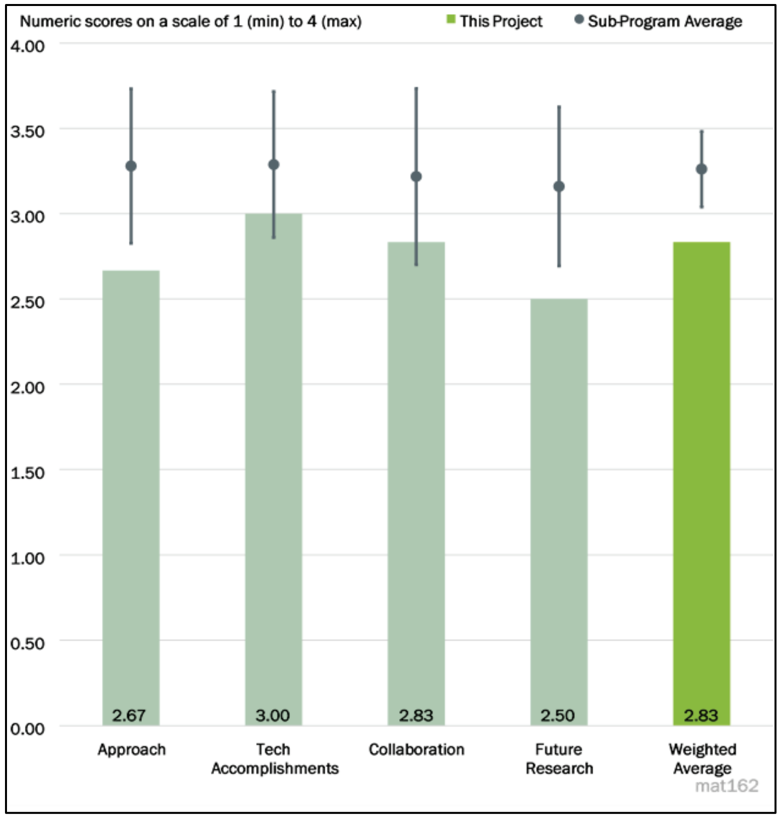

Figure 6-6 - Presentation Number: mat162 Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the presenter did a good job of describing the approach to performing this work. However, when the machine learning regression training topic was discussed, the presenter would benefit from collaboration with a data scientist. For example, using the Hadamard-Autoencoder for missing data would help (because the presenter said that significant gaps exist with the experimental because it was not conducted with a data analytics focus). Self-supervised learning (SSL) is one of the most promising ways to build background knowledge and approximate a form of common sense for high-performance valve alloys.

Reviewer 2:

In the project team's approach (Slide 4), there does not seem to be experimental feedback to validate or improve the model(s). In the "data analytics" task, for those condition and alloy systems that are outside the predicted range, is there an effort to study why the current model cannot predict it well? Is it due to the lack of fundamental measurement? What is the plan to improve the model used? On Slide 15, the project team conducted successful machine learning (ML) model training but stated it "needs more 'good' reactive force field (ReaxFF) data to improve model accuracy." The reviewer wondered if there is an effort in this project to obtain "good" ReaxFF data.

Reviewer 3:

The goal appears to be to reduce the parabolic constant (k_p), which the reviewer believed will be dominated by more than nickel (Ni). For example, it could be dominated by chromium (Cr) and Al (Slide 7).

The reviewer wanted to know what is the lowest k_p at the operating temperature that the team is targeting and what was that alloy? What k_p level is the research team trying to get to?

The reviewer suggested that the talk should have a summary slide on the mechanism(s) and model(s) around which the ML and some sort of ranking of the mechanisms take place to avoid teaching mechanisms with a limited effect. Basically, how were the ML values predicted?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project team introduced ICME-based physical constraints to the ML model. Nichrome (NiCr)-based alloys with better oxidation resistance were predicted. Hopefully, the reviewer noted, these data can be provided to the experimental team to further evaluate these alloys.

Reviewer 2:

Good progress has been made toward the goal. It would also be nice to show what missing gaps are in the data that are required to arrive at an optimized experimental alloy based on the oxidation prediction behavior. The reviewer thought that 18 degrees of freedom is very challenging. A more detailed focus on microstructure experimental and ICME could be helpful to reaching the researcher's goal.

Reviewer 3:

The reviewer indicated that good progress has been made if all that is trying to be done is to match the k_p of available alloys to the experimental data. How bad is the best alloy that is available today? What is the research team's goal and how far is the team from the goal or metric?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The researcher is a good metallurgist, but the reviewer opined that collaboration with a data scientist could help reach a good model to predict corrosion and oxidation.

Reviewer 2:

There is good collaboration between national laboratories, universities, and Industry. The reviewer would have liked to see an engine builder on the team.

Reviewer 3:

The reviewer was not clear how the tasks are distributed among the project teams. It seems the majority of the work was done by ORNL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer said that it appears the project is about to end in September 2021.

Reviewer 2:

The reviewer stated that proposed future research was not exactly shown during the presentation. More work on alloys with titanium (Ti) additions besides the main ones of Ni22Cr+xAl and one Ni22Cr+xAl+yTi could also help.

Reviewer 3:

This reviewer asked what the research team hopes to predict at the end and whether the team will make alloys if ML says something unusual. What about titanium aluminide (TiAl) and other alloy systems, or is it only NiCr? The reviewer further inquired as to whether the team has exhausted this well-studied system and if it is time to move on.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, if the new materials could allow the engine to run hotter, then the engine would be more efficient and have a lower carbon footprint.

Reviewer 2:

The reviewer would have answered "yes" if the research team were trying to make a big change, but the team is too focused on NiCr-based alloys that have already been studied in great detail. Also, there are too many factors other than temperature that drive fuel economy of engines. How will the team predict the unknown?

Reviewer 3:

The project seems to support the overall DOE objectives by developing tools to quickly narrow down the alloy systems with good corrosion and oxidation resistance. However, the reviewer was still struggling to understand how effective this project and approach can be. The effort proposed and made in this project does not seem to address the barriers listed by the project team. For example, "lack of fundamental alloy oxidation data (e.g., atomic mobilities in oxides, oxygen permeability)" seems to remain a barrier after the completion of the project.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed that the researcher has completed a lot of work in just Quarter (Q)1 of FY 2021 and Q2 of FY 2021.

Reviewer 2:

The reviewer opined that ORNL has sufficient computation resources to achieve the project.

Presentation Number: mat163
Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components
Principal Investigator: Mei Li (Ford Motor Company)

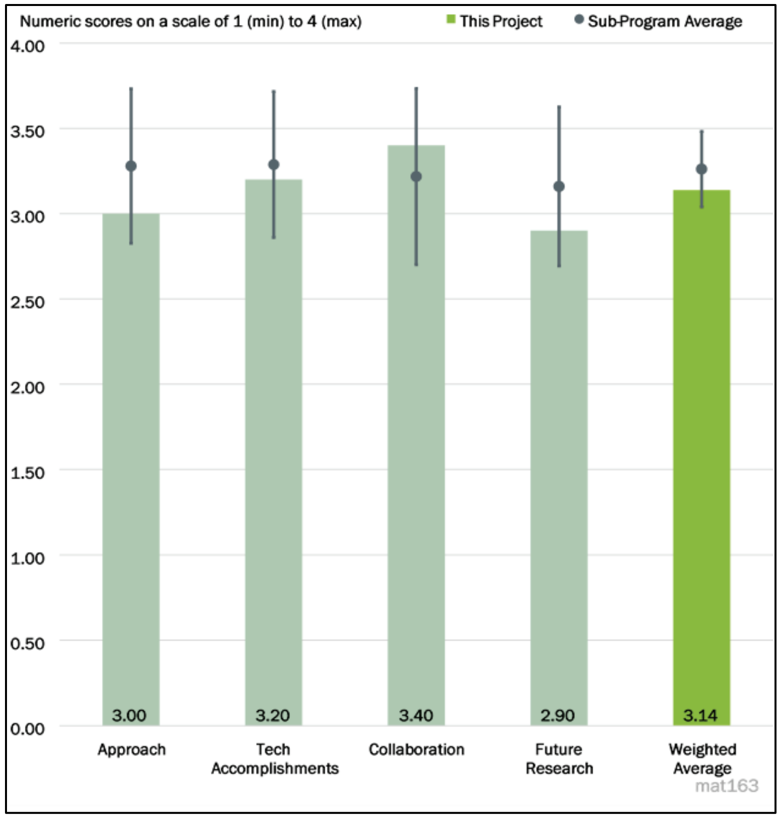

Figure 6-7 - Presentation Number: mat163 Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components Principal Investigator: Mei Li (Ford Motor Company)

Presenter

Mei Li, Ford Motor Company

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The researcher has done a good job with the approach being both theoretical and experimental. The use of density function theory (DFT), ReaxFF molecular dynamics (ReaxFFMD), potential energy landscape (PEL), and diffusion-controlled phase transformation (DICTRA) was very interesting to the reviewer.

Reviewer 2:

The approach consists of applying a number of existing models (at different scales) and validating them through oxidation and thermomechanical fatigue simulations. Whether the models lead to any real insights or whether they serve as an exercise in complex curve fitting was not clear to the reviewer. Given the complexity of the physical phenomena being modeled, the reviewer thought that it may be the latter.

Reviewer 3:

While the individual ICME approaches intended to be used in the project are good at their respective length scale, the approach outlined to integrate among these ICME tools has a weakness. Also, atomistic simulations (DFT and ReaxFF) appear to be limited to very simple alloy systems (such as pure Fe or simple binary and ternary) instead of engineering alloys. Also, it was not clear to the reviewer how thermochemical fatigue (TMF) was predicted from the computational approaches in the project.

Reviewer 4:

The presentation should have included the barriers to deployment, but they are not specifically presented. The reviewer could infer what the research team is trying to do, but the actual failure modes that this is preventing are not presented.

According to the reviewer, it would improve the project to state what the barrier to deployment is and what the research team is trying to prevent from happening. The work jumps into issues that occur at a molecular level but does not relate that to in-service issues. Also, there are no data on possible cost implications.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The multi-scale modeling of the oxidation process is well presented and the use of several existing models in tandem is a great approach. Understanding the contribution of each type of fatigue on the failure process is paramount in being able to design or select an alloy that is optimized in both performance and cost. The reviewer asserted that nice work has been done in this area.

Reviewer 2:

Good development has been made in understanding oxidation layer growth kinetics and the "elephant skin" surface structures that result in low TMF life and measuring the oxidation layers and failure analysis while comparing it to the predicted data. The reviewer indicated that a lot of good work has been completed between the last AMR and today.

Reviewer 3:

The reviewer noted that progress this year was good although it slowed down compared to the original plan due to COVID-19. Progress was made on both the experimental and modeling fronts such that this project is moving toward a successful conclusion.

Reviewer 4:

The theoretical components of the project appear to be too focused on the lower length scale, and it was not clear to the reviewer how these results can be correlated with the actual situation. Experimental evaluation is excellent and thorough; however, it is hard to connect to the theoretical studies.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the Principal Investigator (PI) has assembled wonderful collaboration between industry (Ford Motor Company) and academia (Ohio State University, the University of Michigan, and Missouri University of Science and Technology) and national laboratories (ORNL).

Reviewer 2:

The reviewer praised the collaboration as excellent for the present effort with an OEM lead (Ford) and multiple university and national laboratory partners.

Reviewer 3:

The reviewer indicated that this project has a good combination of different ICME capabilities and experimental validation across multiple institutes.

Reviewer 4:

Regarding collaboration, the reviewer had to make an assumption as the data and samples presented are not attributed to any source, so it is hard to understand if all the team is involved. It would be good to identify the data, image, and sample sources in the presentation so that the collaboration is visible.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the plan for future research was appropriate, given the wider goals of the program.

Reviewer 2:

A clear plan for future research includes basic research toward understanding energic properties of the Fe/graphite interface with the presence of impurities. It is always an issue trying to get multi-scale models to translate from micro-scale to meso-scale and macro-scale. The reviewer looked forward to seeing the demonstration results on CrNi-type austenite steels.

Reviewer 3:

The future research is presented but the reviewer remarked that it would be more impactful if the implications of successful completion of the listed tasks were explained. This is also more focused on the tasks and not the impact of the project.

Reviewer 4:

The reviewer asserted that theoretical components of future research are too focused on atomistic length scale, which cannot provide insights into long-term and large-scale phenomena that are relevant to corrosion and oxidation of alloys.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The project addresses a critical scientific gap for the thermomechanical fatigue life prediction of a material susceptible to oxidation damage. The generated knowledge will serve the larger community as well, according to the reviewer.

Reviewer 2:

The reviewer stated that this project is highly relevant to the DOE VTO mission.

Reviewer 3:

The reviewer commented that the development of heat-resistant alloy solutions meets the increased exhaust temperature requirement, which leads to reduced automotive emissions and a lower carbon footprint.

Reviewer 4:

The presentation explains that this project supports increased combustion temperatures, and that, in turn, leads to lower emissions, but lacks details about how this is necessary for that. The reviewer could infer that this is just a cost optimization activity from the presentation, but more information on this would help align it to the objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The multi-scale modeling requires a tremendous amount of resources, but the reviewer remarked that the PI is using the resources very well.

Reviewer 2:

The reviewer noted that the pandemic has affected the team’s original timeline, and the researchers are rebounding.

Reviewer 3:

According to the reviewer, the project has sufficient and appropriate resources to carry out the research.

Reviewer 4:

The reviewer deemed resources available to be sufficient.

Presentation Number: mat164
Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials
Principal Investigator: Michael Tonks (University of Florida)

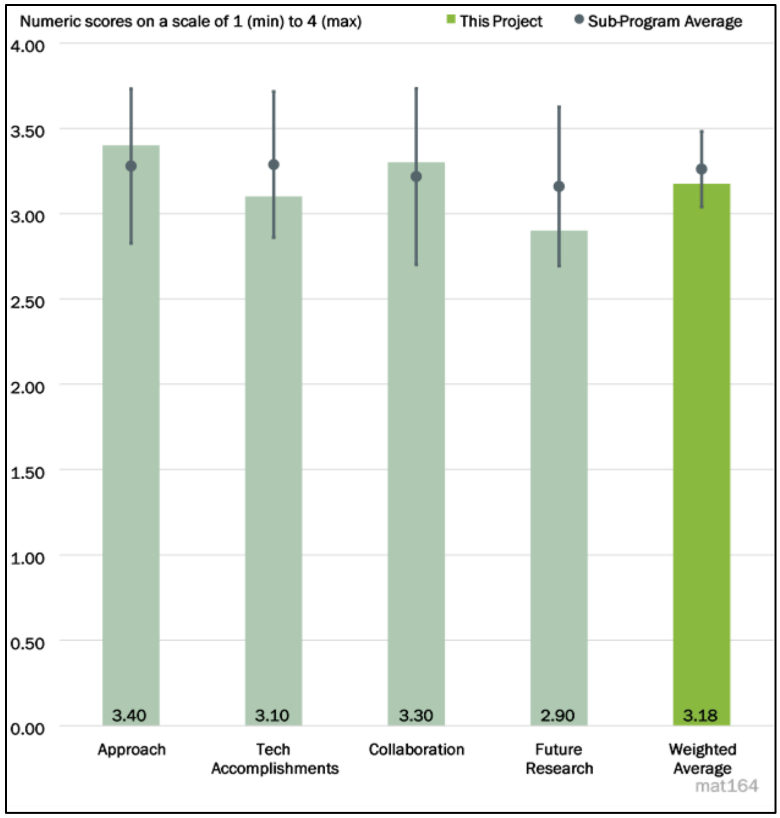

Figure 6-8 - Presentation Number: mat164 Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials Principal Investigator: Michael Tonks (University of Florida)

Presenter

Michael Tonks, University of Florida

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the PI's approach is good toward the goal of Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High Temperature Engine Materials. The calculations with DFT and MD being used to determine diffusion barriers was very interesting to the reviewer. The PI also investigated the diffusivity of metallic species in both alloy and oxide phases. The reviewer indicated that using the Idaho National Laboratory (INL) object-oriented C++ finite element framework for developing the tightly coupled multiphysics solvers multiphysics object-oriented simulation environment (MOOSE) program is a good approach toward this goal.

Reviewer 2:

There is a very clear set of expectations, and the project is well presented. It was clear to the reviewer what the research team intends to achieve and what barriers are needed to overcome.

According to the reviewer, it would improve the presentation if the team would quantify the extent and expense of current mandated "conservative design." This could be a huge win or maybe just a small victory, based on how conservative the design is, so that should be quantified. It could be as simple as comparing the recommendation from the project to the current production material in a real-world application at the end of the project or using historical data.

Reviewer 3:

The reviewer wanted more information on the following: What are the operating mechanisms being addressed by the tool? The multi-scale approach is shown, but what all goes into the model? It is interesting that higher Cr is not necessarily better. Is there anything specific to learn from this observation?

Reviewer 4:

This project envisions streamlining theoretical and experimental tasks at different length scales. While it is a highly ambitiously designed project to tackle grand challenges, some components heavily rely on input parameters for simulations. Also, MOOSE oversimplifies the mechanism of complex alloys oxidation scale formation and growth, and again, it highly depends on the parameters for the simulations.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The researcher has made good progress by using both theoretical and experimental data. The model was used to investigate mechanisms for oxide growth and then compares the results to the experimental data. The diffusion behavior, DFT, and MD are interesting. The vacancy transport and stable spinel are good accomplishments.

Reviewer 2:

The reviewer noted excellent conclusions/observations: oxide growth is limited by p-type MnCr2O4 spinel inner oxide growth; and 21Cr-2Ni-8.5Mn has parabolic growth but spallation was observed in 23Cr-8Ni-1.5Mn body-centered cubic (BCC) transformation near metal and oxide interface due to Mn depletion.

Reviewer 3:

It was clear to the reviewer that the research team is completing the process and working toward the deployment of the code. The details are well represented and clearly defined. It is very nice that the team has included a Gantt chart to explain the progress and what is happening next. It is, however, a concern that the tool does not yet consider the impact of microstructure or alloy composition. This is cited as an issue, but no resolution is offered.

Reviewer 4:

The team's accomplishment on atomistic calculations is good; however, it was hard for the reviewer to connect to the larger scale phenomena. Also, the SStAC tool appears to handle "flat" metal and oxide interfaces efficiently, but it is not clear how all of the parameters (such as diffusion kinetics and atomic mobilities of all of the species that participate in the oxide scale growth) are obtained.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer asserted that the PI has assembled a wonderful collaboration between industry (Tenneco), academia (University of Florida and University of Wisconsin), and national laboratories (INL).

Reviewer 2:

The presentation clearly cites what entity created the data for this, making it obvious to the reviewer that the team collaborated and has leveraged resources from each of the participants.

Reviewer 3:

The reviewer found good collaboration between university partners and industry material suppliers.

Reviewer 4:

The team consists of individuals with diverse research expertise and backgrounds, according to the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer opined that the researcher has to get to the point of using computer coupling of phase diagram and thermochemistry (CALPHAD) free energy bands of Mn and Cr and incorporating them into the model.

Reviewer 2:

The reviewer stated that the project offers a good proposed future research plan.

Reviewer 3:

While the presentation states that the research team is recommending adding alloy composition and microstructure from a mesoscale range, the issue for the reviewer is that these properties are driven at a much smaller scale and there is no opportunity to understand that relationship and add it to the model.

Reviewer 4:

The tool will explain the behavior within a certain boundary of chemistries. How is direction for a better alloy being defined? Can the tool be used to get out of this alloy system and develop a tool that looks at other alloy systems because not much more can be done with this alloy system? Although the reviewer noted that work did show that BCC transformation near the metal/oxide (M/O) interfaces due to Mn depletion was important, how can the depletion be reduced? While the work focuses on nanoscale phenomena, are there any micron-sized phases whose interfaces could be the problem?

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the use of the SStAC tool for high-temperature engine materials will allow the engines to run hotter, be more efficient, and have a lower carbon footprint.

Reviewer 2:

The reviewer said that this project is highly relevant to DOE objectives.

Reviewer 3:

The presentation says that the SStAC tool must predict a corrosion rate with less than 10% error. It is not shown to the reviewer that this level of accuracy is sufficient or what level is necessary. Why does it have to be less than 10%? How would it change the capability if it were 20% or 5%?

Also, the presentation never ties this directly to an initiative at anything larger than a component scale. The reviewer wanted to know what the important is of getting this 10% ability in the model and whether it will change in the engine performance.

Reviewer 4:

The reviewer responded that the answer would have been “yes” if the team were trying to make a big change. How will the team predict the unknown?

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The predictive modeling of corrosion sensitization of valve steels at high temperatures requires a lot of resources but the reviewer said that the PI is using the resources well.

Reviewer 2:

The research team is on track to complete the project. The reviewer noted that nothing is missing. Additionally, the team is clearly not working ahead. It looks like the resource level is correct.

Reviewer 3:

The reviewer commented that the resource level is sufficient, at least from the list of contributors.

Reviewer 4:

The project has a sufficient level of funding to perform the proposed research, according to the reviewer.

Presentation Number: mat173
Presentation Title: Self-Sensing Fiber-Reinforced Composites
Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

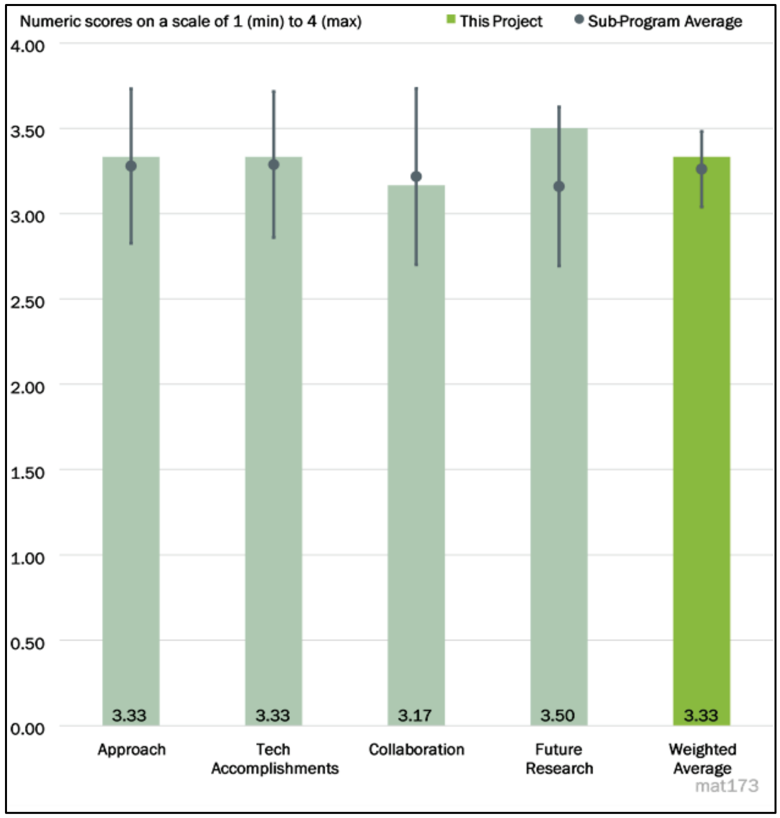

Figure 6-9 - Presentation Number: mat173 Presentation Title: Self-Sensing Fiber-Reinforced Composites Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

Presenter

Christopher Bowland, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This work has evolved since 2019. Overall, the concept is the use of titanium oxide nanoparticles with CFs to aid in structural health monitoring applications. The proof of concept was demonstrated via straining of the coated CFs to measure variation in a strain field. The interlaminar shear strength was optimal in the 1–2.5 weight percent (wt.%) range. Overall, the concept has been proven through systematic studies. The illustration of basalt-coated barium titanate ($BaTiO_3$) with CF as a hybrid system was demonstrated, which seemed to be an advancement to the reviewer.

Reviewer 2:

The project approach was well executed through testing various concentrations and their effect on material performance. The work also evaluated the effect of resistivity related to concentration and strain. This is an excellent approach to determine the gauge factor. The reviewer was impressed with how high the gauge factor was in relation to traditional strain gauges of two. The reviewer thought that the most challenging data to collect with this system will be the measurements transverse to the fibers, and they may be the most sensitive to strain. The concentration effects may be different on the transverse resistivity.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer observed a nice job of reaching and exceeding the target goals. Additionally, the milestones and metrics were all exceeded. The reviewer explained that one thing that could have improved the performance metric is comparing the measurements to a conventional strain gauge or using a strain gauge and comparing real-time data between the two.

Reviewer 2:

The project made advances in fabrication of multi-functional composites with a Ti-based coating of carbon (C) and basalt fibers and characterization of the interlaminar shear strength (ILSS). The research team demonstrated and characterized the active and passive sensing capabilities. For passive sensing the team used a hybrid composite approach. Researchers illustrated the power generation of the hybrid composite in response to strain. Overall, the reviewer found that the set milestones were aligned with the accomplishments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The main listed collaboration partner was Dronesat, LLC, although it was not entirely clear to the reviewer at what stage Dronesat got involved with the project or if there were beneficiaries of the work after the technical tasks were accomplished. The technology has a broad range of use. However, in this project the collaborations were rather limited and there was less emphasis on broadening the collaborations. The project team engaged interns in the effort, as evidenced by the illustrations.

Reviewer 2:

The project transitioned to a company collaborator looking at a specific application. The project did not have initial industrial participation. According to the reviewer, the project has lots of opportunity to transition to industry participation.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that the project has ended, but the team did transition to a new project with an industry collaborator.

Reviewer 2:

The reviewer said that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The DOE objectives of lowering embodied energy and increasing the life span of structures align with this effort. The overall effort has a broad range of applicability in structural health monitoring of wind blades, power plants, structures, buildings, aerospace, and automotive components as examples. This project had limited collaboration; however, the reviewer said that the technology can apply to these areas.

Reviewer 2:

The reviewer stated that real-time monitoring of damage in composite materials can improve processing evaluations, in-use composite performance measurements, and safety. This would reduce material waste and increase material component use without prematurely removing from the service.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer remarked that the ORNL team has all the resources to conduct this work within the organization, such as CF and coating technologies, mechanical testing, electronics and electrical measurements, and the microscopy and evaluation facilities.

Reviewer 2:

The reviewer asserted that the project was completed in a timely fashion with excellent results to show for the money spent.

Presentation Number: mat174
Presentation Title: Carbon-Fiber Technology Facility (CFTF)
Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)

Presenter

Merlin Theodore, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

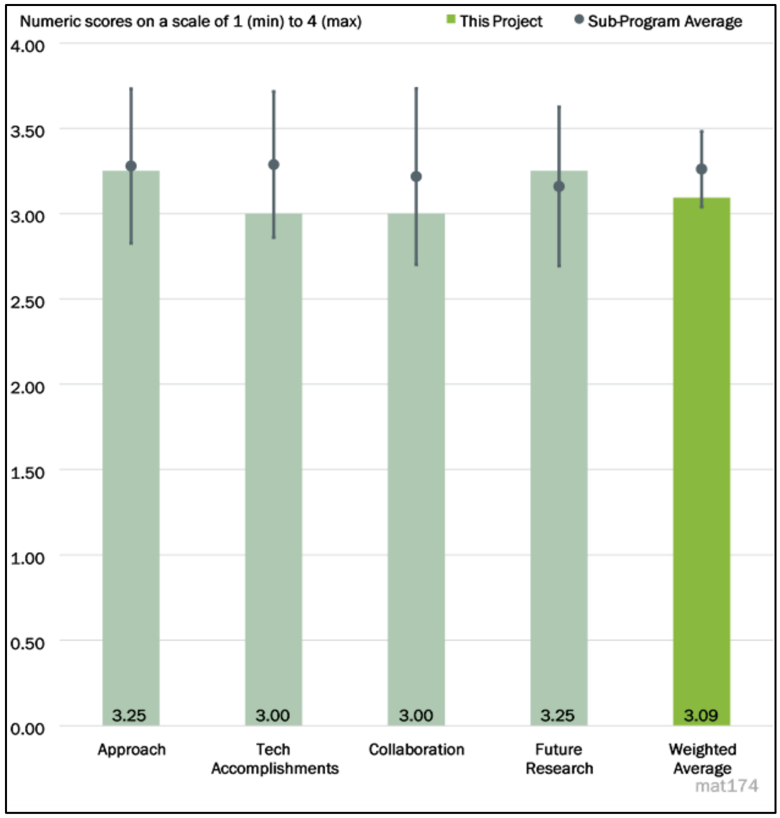

Figure 6-10 - Presentation Number: mat174 Presentation Title: Carbon-Fiber Technology Facility (CFTF) Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the Carbon Fiber Technology Facility (CFTF) is a unique R&D facility that helps pilot-scale and industry-scale research. The approach includes low-cost conversion of polyacrylonitrile (PAN) and the development of alternative precursors. The projects are well designed and very feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the precursor fiber lines and conversion processes/lines are well designed and help reduce CF costs. Further, the reviewer stated that alternative precursors are promising toward meeting DOE targets.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration at CFTF has been excellent. The reviewer remarked that the team has been working on projects with universities and industry sectors.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Several projects have been planned and are on track. The road maps and target metrics made sense to the reviewer. The decision points and barriers are well considered. It would be helpful if more CF companies are involved in the CFTF for their R&D.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The VTO project at CFTF supports the overall DOE objectives. The reviewer opined that low-cost CF is critical for EVs and low-C emissions.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The CFTF has sufficient resources for lab-scale, pilot-scale, and industry-scale CF research. According to the reviewer, the VTO project at CFTF has achieved the stated milestones in a timely fashion.

Presentation Number: mat183
Presentation Title: High-Temperature Coatings for Valve Alloys
Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

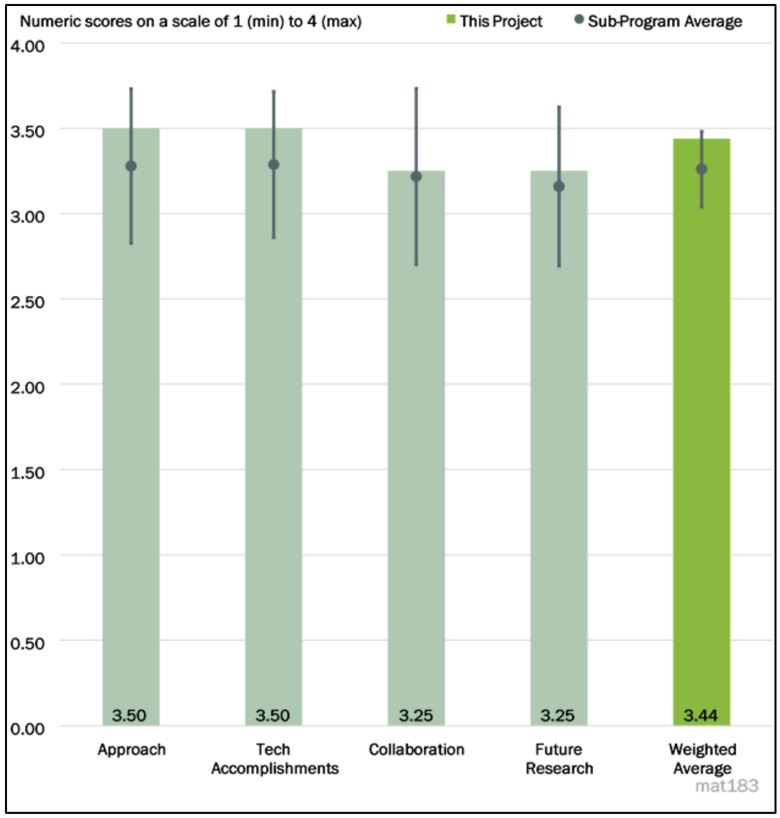

Figure 6-11 - Presentation Number: mat183 Presentation Title: High-Temperature Coatings for Valve Alloys Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Presenter

Sebastien Dryepondt, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer identified High-Temperature Coatings for Valve Alloys - Research Thrust Area 2A3: Cost Effective Higher Temperature Engine Alloys (with some additional funding provided by Subtask 4B – Advanced Computing) under the Powertrain Materials Core Program (PMCP). The approach used to investigate the impacts of many different materials for powertrain use in the Powertrain Materials Core Program (PMCP) is excellent, according to the reviewer.

This approach will be used to Improve elevated temperature oxidation resistance of high-strength valve alloys. The reviewer noted that this process will accelerate coating development time in a cost-effective manner that will ensure compatibility between the alloy substrate and the coating.

By developing and applying an oxidation-resistant alumina-forming coating on a chromia-forming substrate, the reviewer stated that there is an opportunity to place oxidation-resistant coatings on the highest temperature regions of valves, which could significantly improve component lifetime at temperatures greater than 850 degrees Celsius (°C). These high temperatures are common in newly developed, highly fuel-efficient internal combustion engines (ICEs).

Reviewer 2:

The reviewer found that the project efficiently identified a key ingredient (Ti) to prevent oxidation on Al alloys and successfully demonstrated it through tests.

Reviewer 3:

The project is an ideal test bed for the evaluation and transfer of technology that is proven in other applications (aerospace) to more broadly distributed applications in the automotive sector. The proposed approach and supporting micrography are what would be expected of ORNL work and are very supportive of the conclusions being drawn. A broader study using alloys that are expected to have different phase kinetics at the surface would have been extremely interesting to the reviewer, but the team seems to suggest that this gap will be addressed by developing the appropriate models (direct comparisons of alloys 31V to ORNL-1 are presented so there are some examples of different behaviors). The project budget is not exorbitantly large, so this may be one of the obstacles to a broader evaluation of substrates. The actual limited-scale evaluation of a valve would be extremely helpful, also. The interaction between the coating and a valve seat insert may present additional problems that will require some investigation.

Reviewer 4:

The reviewer commented that the approach is excellent. Using coatings on engine valves to improve the oxidation performance is a reasonable approach. Comparing the performance on multiple alloys is nice. No planned engine testing is a negative because the engine conditions will vary significantly from the laboratory testing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The researchers have proven to the reviewer that it is possible to coat these valves. Slurry coating significantly improved the oxidation behavior of alloys 31V and ORNL-1. However, 31V had a decrease in strength. Critical coating thickness was determined to be a 40 micrometer (µm) coating on ORNL-1 to achieve the higher operating temperature of 950°C. Optimization of the substrate and the coating will be critical to developing a commercially viable product. The ICME approach is an excellent approach to determining this optimization. Leveraging the coupled thermodynamic and kinetics model developed to optimize coatings and predict lifetime was done in PMCP Thrust 4b. The model and characterization have good parallels that can be applied to this project.

Reviewer 2:

The coating performance is encouraging. The impact of Ti on the coating performance was interesting to the reviewer, and the potential of optimizing an alloy to work with the coating is exciting.

Reviewer 3:

Microstructures, phase maps and profiles, and mechanical testing are all present. A case is clearly being made that the approaches are going to provide some level of benefit. The fatigue test results are less compelling to the reviewer than what would be expected. The resistance to oxidation would be a major benefit to fatigue crack prevention, and yet the actual fatigue performance bump is very modest. Is the benefit being offset to some extent by a higher propensity for mechanical cracking on the coated surface?

Reviewer 4:

The project has almost accomplished its initial goals. It would have been better if the project explored more of the modeling and optimization aspect, according to the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the collaboration with the alloy development team is a big plus for the project.

Reviewer 2:

The collaborations are appropriate for the project (there are facilities that provide the actual coating services). A broader contribution would have been interesting also, but is the reviewer understood that the capabilities of ORNL limit the need for additional assistance.

Reviewer 3:

This reviewer noted that the program lead laboratory is ORNL, and partners include Flame Spray Inc. and Stony Brook University. There is active collaboration with Thrust 2, Tasks 2A1 and 2A4; Thrust 4A Advanced Characterization; and Thrust 4B Thermodynamic and Kinetic Modeling.

Reviewer 4:

The reviewer was unable to determine this part of the question.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

In order to determine the acceptable Ti content and optimization, the reviewer asserted that it would be necessary to have a good predictive model. Also, it would be necessary to test the surface property (including wear) of the coating.

Reviewer 2:

The proposed future research is appropriate if not overly ambitious. A broader study demonstrating the manufacturability and robustness across different materials and approach combinations is likely more appropriate than optimizing an ORNL-1 alloy combination. The reviewer said that actual valve testing is needed also, as lab-scale mechanical testing has long been proven to be inadequate as an absolute substitute.

Reviewer 3:

The reviewer reported that future research under this project will focus on the following four activities:

- Determine acceptable Ti content in substrate for excellent coating oxidation resistance at 900°–950°C—optimizing the Ti content in the substrate is critical to keeping costs down.
- Determine optimum substrate and coating combination. The fatigue life is similar to the coated ORNL-1 alloy sample with superior oxidation resistance.
- Conduct fatigue testing in corrosive environment to demonstrate coating benefit.
- Investigate coating homogeneity on an actual valve.

The reviewer suggested that the researchers should consider testing a coated valve in an engine (currently outside the scope of the current project). This would be a good next step for this project.

Reviewer 4:

According to the reviewer, the plans are reasonable and address the remaining barriers.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 2:

The reviewer said that the work is highly relevant.

Reviewer 3:

High-temperature coatings would support the overall DOE objectives, according to the reviewer.

Reviewer 4:

The project has broader implications than vehicle components, although the reviewer opined that engine valves provide an ideal test bed for components subjected to demanding conditions that are prone to failure in fatigue. Coatings, if they can enhance the performance of materials that are lower in cost, would be attractive in other areas as well.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The period of performance is October 2018 until September 2023. The reviewer commented that 50% of the project is complete, and it is on schedule. The FY 2020 budget was $170,000, and the FY 2021 budget was $160,000. The reviewer further reported that the project is on schedule, and the funding appeared sufficient to complete all current and future objectives.

Reviewer 2:

The reviewer noted that the project progress demonstrates that the resources are sufficient for the stated goals, as milestones are being achieved.

Reviewer 3:

It appeared to the reviewer that the provided resources are sufficient for the project.

Reviewer 4:

The reviewer said that resources are sufficient.

Presentation Number: mat184
Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys
Principal Investigator: Yuki Yamamoto (Oak Ridge National Laboratory)

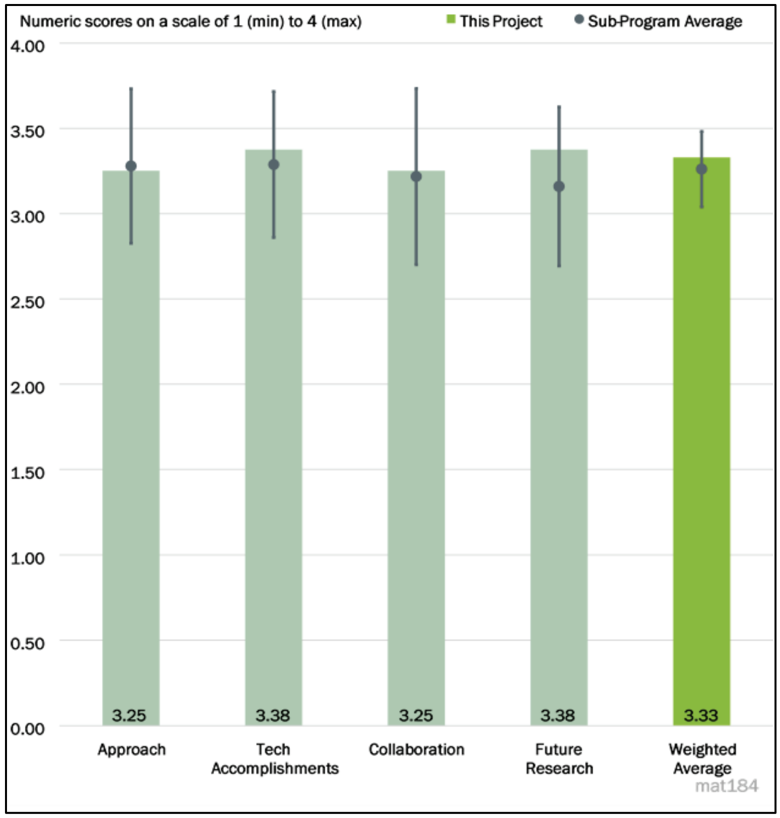

Figure 6-12 - Presentation Number: mat184 Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys Principal Investigator: Yuki Yamamoto (Oak Ridge National Laboratory)

Presenter

Yuki Yamamoto, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is solid, with work this year focusing on process development and optimization to improve the alloys and push toward the technical targets of greater than 900°C. The team is doing a nice job exploring unexpected findings as they arise and exploring root causes. It was helpful to the reviewer that the project team specified the quantitative performance targets this year. Some additional statistical work would be helpful to interpret the results with confidence levels.

Reviewer 2:

The reviewer liked the approach. The use of modeling to accelerate the alloy design is a nice touch. It is also very good that the research team is moving beyond the laboratory scale to industrial heat.

Reviewer 3:

In general, developing a new alloy that pushes the current limitation requires a lot of effort. The project focuses on developing Fe-based alloys that have oxidation resistance at high temperatures, increased strength and creep resistance, and low cost. This is a challenging task, as expected. Without fully understanding metallurgy, it would be difficult to overcome several limitations. Also, the reviewer noted that the project may need a clear target goal to determine its success.

Reviewer 4:

Referencing Research Thrust Area 2B1 – Development of Cast, Higher Temperature Austenitic Alloys under the Powertrain Materials Core Program (PMCP), the reviewer stated that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic for leveraging limited resources and investigating several potential solutions.

The reviewer highlighted the following regarding the Utilized ICME Type Approach to Minimize Iteration slide: alloy design; assessment with laboratory-developed tools; validation on a laboratory scale; and industrial scale up.

The approach to accomplish this project used the ICME stepwise process, which this reviewer listed as follows:

- Cast alumina-forming austenitic alloys that will provide better protection than chromia scale.
- Use ICME (CALPHAD databases) to minimize alloy selection during the iteration process.
- Validate material physical properties in the laboratory via experimentation using 1 pound or less of material.
- Evaluate production feasibility with trial industrial scale-up heats using 50 pounds or greater of material.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Overall, the reviewer found the progress to be excellent. The variation in the creep stress is one issue, but the findings that it is impacted by the yttrium (Y) composition is a necessary initial step to overcoming this.

Reviewer 2:

At the laboratory scale, it seemed to the reviewer that the achievement is significant, albeit too much variation for industry-level applications. It would be necessary to investigate the cause of large variation and identify key factors for quality control.

Reviewer 3:

Based on Slide 5, the reviewer said that one of the four quarterly milestones for FY 2021 has been completed to date with the others still somewhat delayed. The Y findings are some of the most interesting outcomes to the reviewer from the FY 2021 work thus far, so it is good that the team plans to investigate further the role of Y (positive or negative) in the alumina-forming austenitic (AFA) alloys, which will likely involve tradeoffs between oxidation performance and creep performance.

The high-temperature performance results are promising. The reviewer was curious if the project team has explored statistical significance and repeatability for the results provided (e.g., Slides 7, 9, and 14). How many samples were tested of each type to draw conclusions?

Reviewer 4:

This reviewer reported that the objective for this project was to develop Fe-based alloys for vehicle applications (exhaust manifolds and turbo housing)—greater than or equal to 800°-900°C and greater than 260 bar for heavy duty; and greater than or equal to 950°-1,000°C and greater than 103 bar for light duty.

By using alumina (Al_2O_3) scale formation (AFA alloys), improved oxidation resistance can be achieved.

A lab-scale heat of newly developed ORNL-AFA (AFA5, Fe-22Ni-17Cr-4Al base) achieved the balanced properties of oxidation resistance, creep rupture property, and inexpensive raw material cost (comparable to the benchmark steel) and will be moved toward scale-up through the industrial metal process. The reviewer stated that centrifugally cast AFA ingots (in another project under the Advanced Research Projects Agency-Energy [ARPA-E]) exhibited more consistent mechanical properties (good quality cast AFA type alloy is possible).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration seemed good to the reviewer between multiple national laboratories and industry.

Reviewer 2:

The collaboration seemed reasonable to the reviewer, and the research team seems to be coordinating the work between collaborators.

Reviewer 3:

The reviewer stated that the program lead laboratory is ORNL and partners include the Advanced Photon Source (APS) at Argonne National Laboratory (ANL) and the Environmental Molecular Sciences Laboratory (EMSL) at Pacific Northwest National Laboratory (PNNL). The industry partner, MetalTek International (materials supplier subcontractor), is working closely with Thrust 4B researchers. An example of laboratory-to-laboratory collaborations was ORNL working with PNNL on "Microstructure Characterization to Understand Improved Creep Performance in Lab-scale Cast AFA5." The reviewer indicated that there is no interface with universities for this project.

Reviewer 4:

Partnerships are in place through the PMCP, though it was a bit unclear how closely knit the collaborations were in this specific project because all the external partners seem to be working under Thrust 4 while this project falls under Thrust 2. There was one mention of a PNNL collaboration and no mention at all of ANL, though both are listed as contributors to this project. The reviewer wanted to see more detail on the inter-thrust collaborations. Industrial partner MetalTek produced the cast ingots and seems to have had some good collaboration with ORNL in process optimization for AFA alloy casting.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The future plans are good and address the observed barriers and issues. The reviewer noted that the investigation into alternatives to Y is especially important.

Reviewer 2:

Proposed future work seemed appropriate and valid to the reviewer. A major focus should be on the September go/no-go decision to initiate scale-up of cast AFA for exhaust components.

Reviewer 3:

The reviewer opined that it would be better if the future research focuses more on understanding the metallurgy and parameter study to identify dominant factors for quality control.

Reviewer 4:

The reviewer suggested that quality improvement of commercially cast components is still needed, including melt temperature, pouring technique, mold design, and others requiring improvement for manufacturing processes, and alloy design modification and compositional optimization for material characteristics.

The reviewer commented that downselected cast AFA5 moved to scale up through industrial melt processes and led to excellent oxidation resistance at 950°C comparable to the laboratory-scale heat. The observed variation of creep-rupture performance was due possibly to inhomogeneous defect formation and/or local high Y level impacts.

Investigating the source of the creep-performance variation led to relatively high Y contents in industrial heats, researchers considering the combined effect of aluminum oxide and the mold size, and proposing both allow and process optimization, which are currently in progress.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles. It was noted that alumina-formers may also offer enhanced resistance of attack from alternative fuels, such as natural gas, biofuel, or hydrogen.

Reviewer 2:

The reviewer stated that the work is highly relevant.

Reviewer 3:

The project is closely related to the overall DOE objectives, according to the reviewer.

Reviewer 4:

The reviewer said that this project supports DOE objectives related to lightweighting and high-temperature materials performance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Several milestones were delayed because of restricted access to the laboratory during the COVID-19 pandemic. Although this project's schedule has slipped, the reviewer commented that resources remain adequate as activity was delayed and funding should be sufficient.

Reviewer 2:

It seemed to the reviewer that the project team has enough resources to develop the new alloy.

Reviewer 3:

Resources appeared to be sufficient to the reviewer for this effort.

Reviewer 4:

The reviewer said that resources are sufficient.

Presentation Number: mat185
Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing
Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

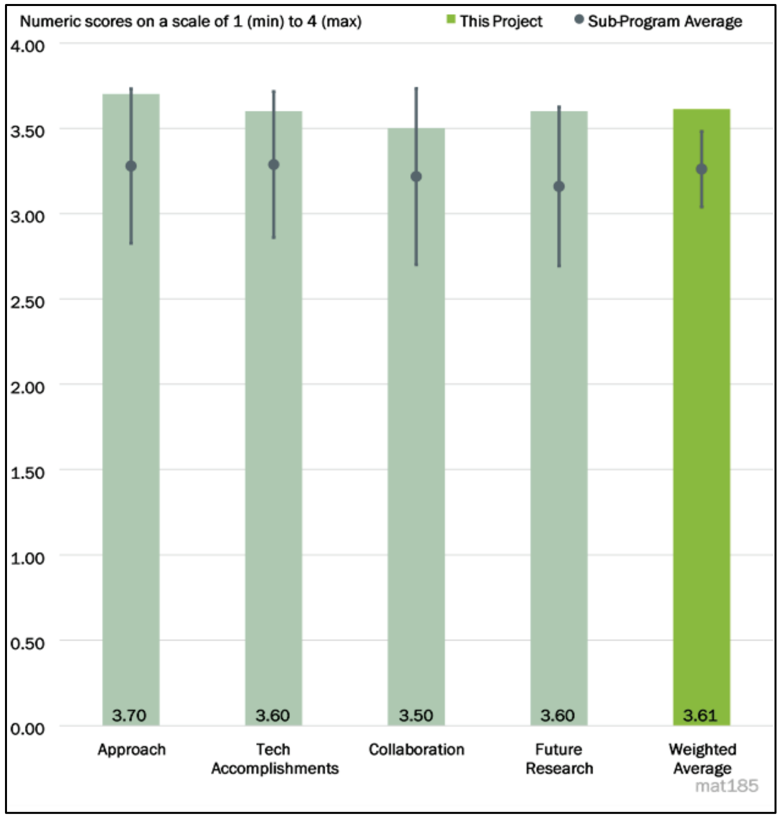

Figure 6-13 - Presentation Number: mat185 Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

Presenter

Derek Splitter, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach addresses a method that enables accessing new material properties with conventional alloys using an additively manufactured reinforcement and preform process and a vacuum melt infiltration method to address two of the technical barriers that are identified in the presentation. Advanced materials characterization, tensile testing, and modeling of the results are described that address the ability of the new materials to withstand the high-energy impact forces experienced by pistons in a combustion engine. The reviewer affirmed that this is an outstanding technical approach to solve the problems with high-temperature engine environments.

Reviewer 2:

The reviewer remarked that this is a great project that is well balanced between modeling and experimental work. This is essentially an extension of composite material in three-dimensional (3-D) printing. The real impact can be expected if the feature size of a 3-D printed structure is further reduced, and infiltration can reduce the size and number of pores. It was especially great that the PI explored the possibility of damage de-localization, which can be a major issue in material performance.

Reviewer 3:

The project aims to address piston failure from knock and stochastic pre-ignition (SPI) rouge cycles in excess of 300 bar, abnormal (knock) events. These knock events can be catastrophic failures, even for a single event. Additive manufacturing (AM) processes can create heterogenous materials that provide target material characteristics. This allows the researchers to locally tailor the material to the preferred mechanical properties for the material. The reviewer stated that this is a direct approach to produce multi-metallic components while enabling opportunities for lightweighting. Researchers are also investigating micro features with digital image correlation. By using finite element analysis (FEA) modeling, researchers can "see" into the material.

Reviewer 4:

The project is well designed and well planned. According to the reviewer, the technical barriers have been addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

A significant technical accomplishment was the demonstration that a change in the volume fraction of 316L stainless steel will significantly increase the energy to fracture a composite material test sample. This finding was supported by FEA that showed that damage and failure occurred in a single localized location in the material and that the increased volume fraction helped to distribute the load that was applied. The analysis also showed a significant finding of the effect of a bending load on the lattice structure at the node junctions, and these findings were supported with microscopic analyses. According to the reviewer, another significant technical accomplishment was the use of hot isostatic pressing (HIP) to close the pore structures in the Al alloy and the composite 316L/A355 material, thereby reduces debonding at the composite interface. This interface bonding was shown to affect the mechanical performance for strength and ductility when the interface is removed but reduces energy adsorption potential when the bonding is strong. These are all outstanding technical accomplishments.

Reviewer 2:

The reviewer asserted that the project shows top-notch research on designing, building, and testing an AM composite that can show damage delocalization. This is really a boundary between AM and conventional composite materials. The research is well balanced by modeling and simulation and testing.

Reviewer 3:

Special focus is given to the interface and shock modeling was also developed. This aligns with the researchers' attempts to delocalize damage enabled by dramatic energy to fracture improvements (by five times). This provides high damage absorption potential for extreme conditions. Also, the researchers found that bonding is critical in energy adsorption. Other applications that require energy adsorption material properties can use these materials. The reviewer commented that progress has been made to develop high damage tolerance materials with a novel early stage, bi-metallic system.

Reviewer 4:

The reviewer said that the team presented the combination of digital image correlation (DIC) measurements and FEA model analyses that revealed the mechanism by which the PrintCast composites' energy absorption property transitioned under uniaxial tension. The team investigated the role of interface between constituents and characterized the interface systematically. The team produced one journal paper, and two manuscripts are under preparation.

The post-processing of HIP effectively closed the interface gap. However, the HIP is not an efficient process to be applied in industrial manufacturing. The reviewer encouraged the project team to develop a method to replace the HIP post-process for industrial applications.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There is an excellent team for collaboration on this project, which included two universities (for early-stage vacuum casting development), a large service company, a Department of Defense laboratory, and internal coordination with test facilities and other project Principal Investigators at ORNL. The reviewer said that the only improvement could be the inclusion of an OEM from the automotive industry. Close coordination during the planning phase is evident.

Reviewer 2:

This reviewer described collaboration with the university, Air Force Research Laboratory (AFRL), and industry as excellent.

Reviewer 3:

The reviewer remarked that the ORNL team—in collaboration with Rice University and the Massachusetts Institute of Technology (MIT)—is well organized and has progressed the tasks effectively.

Reviewer 4:

Partners on this project include ORNL (leading laboratory), MIT, AFRL, Rice University, Quintus Technologies, and Bechtel (broader Advanced Materials Intelligent Processing Center [AMIPC] work). The team is also working closely with Task 3B1 researchers in the development of lattice material. The reviewer noted that there is good coordination among partners and a balanced team of national laboratories, university participants, and an industry partner.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The future research described is consistent with the approach and strategy to address the DOE VTO technical targets and barriers that will allow acceptance of the technology and models by the end-user. The next steps in this research project were logical to the reviewer and will continue to address the challenges using the new alloy systems developed at ORNL. The future work also includes a scale-up demonstration, which will be valuable for transitioning of the technology being developed.

Reviewer 2:

The future plan of studying coatings is good as it is related to many other DOE project activities. Applying the current technology to other alloys already shows some progress. Fatigue is of the utmost important performance; therefore, the reviewer said that it is important to investigate the fatigue performance.

Reviewer 3:

The reviewer stated that the researchers' next steps will be evolutionary developments toward full-scale demonstration solutions. Future work focuses on lattice geometry effects on shock loading and scale-up to component level problems.

Reviewer 4:

Future work focuses on lattice geometry effects on shock loading and scale-up to component-level problems. The reviewer asserted that it will be better to include a good post-processing method applicable to industrial manufacturing.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project directly supports the overall DOE VTO technical targets and U.S. DRIVE roadmap (which includes DOE) goals for material development and predictive modeling and simulation of high-performance materials used in internal combustion engines.

Reviewer 2:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 3:

The reviewer said that that the scope of work is well aligned with the overall DOE objectives.

Reviewer 4:

The reviewer noted that the project is closely related to DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The funding is about $200,000 per year which is sufficient for the composite material development, the characterization and analysis of the new alloy compositions, the software development for failure analysis, and the scale-up demonstration. According to the reviewer, the number of researchers and collaborators are adequate for each technical area being addressed.

Reviewer 2:

This project is on schedule and the funding appeared to the reviewer to be sufficient (FY 2020 was $205,000 from AMIPC and FY 2021 was $190,000 from AMIPC) because all stated milestones have been completed on time (to date). The project is 50% complete with 50% of the schedule to go.

Reviewer 3:

The reviewer commented that the team has sufficient resources to carry out the planned tasks.

Reviewer 4:

It seemed to the reviewer that the project is progressing well with the current support.

Presentation Number: mat186
Presentation Title: Modeling of Light-Duty Engines
Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

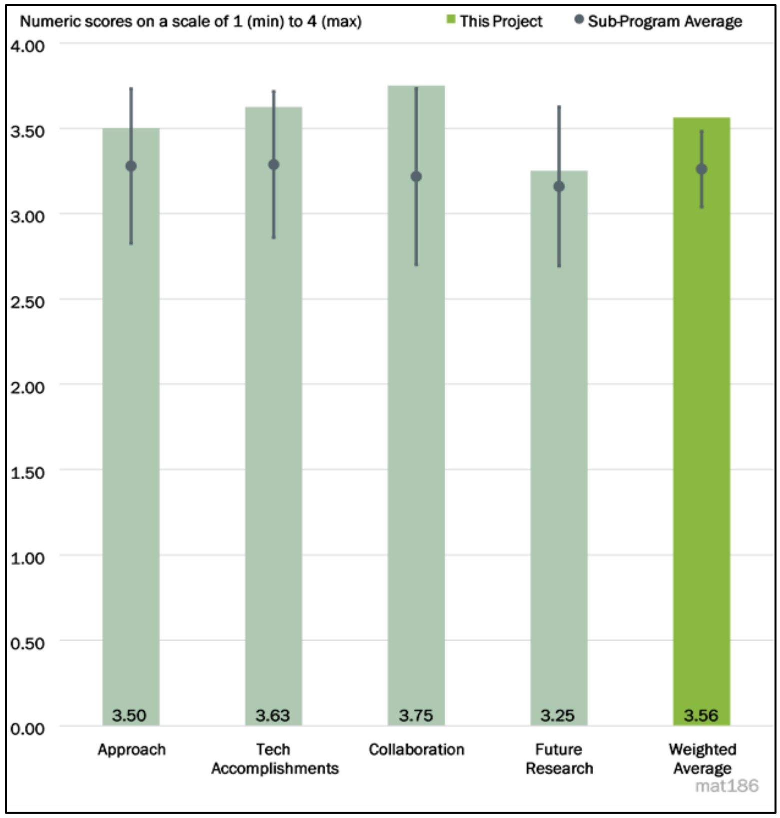

Figure 6-14 - Presentation Number: mat186 Presentation Title: Modeling of Light-Duty Engines Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

Presenter

Charles Finney, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the project is focused on engine modeling for light-duty vehicles. The specific outcomes are determining the engine operating conditions under various engine power densities and determining the required material properties for the engine components that will perform reliably. The project is using computational fluid dynamics (CFD) and thermal modeling to address these barriers. In addition, the project is leveraging other DOE VTO materials development projects, specifically within the PMCP, to define the material properties that would be needed for higher efficiency engines.

Reviewer 2:

This project represents a collaboration between combustion and materials scientists aimed at the development of improved computational models to assess the impact of new materials development on engine performance. The reviewer remarked that the approach involves co-simulation of combustion and materials' thermal properties that are measured for the new alloys being developed under VTO programs. It includes validation efforts together with efforts to measure relevant materials properties required as the input.

Reviewer 3:

The reviewer stated that the approach addresses defined technical barriers and is feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This is a 2-year project. The team has made excellent progress in the modeling of the engine using low- and high-dimensional models to establish the engine performance and the target material properties. The reviewer said that the project in on track in terms of progress.

Reviewer 2:

The reviewer noted that good progress was documented in simulations to explore the impact of new materials on higher specific output.

Reviewer 3:

The reviewer indicated that the project is progressing relative to performance indicators and milestones.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This is a relatively modest effort that nevertheless mentions sharing of methods and materials properties with a much broader engine modeling community. Explicit mention was made of the partnership with five different PMCP tasks and the Partnership for Advanced Combustion Engines (PACE) program for property inputs and validation data. It also involves collaborations with Convergent Science, Inc., in the area of model development and validation. The reviewer asserted that this is an impressive level of collaboration and partnership.

Reviewer 2:

The project team is collaborating with the other teams working on other materials development and in advanced characterization and computation thrust areas as part of the PMCP. In addition, there is external collaboration with Convergent Science, Inc., in the area of engine simulations and PACE. As evidenced by the progress, the collaboration across the various partners and collaborators appeared to be quite fruitful to the reviewer

Reviewer 3:

Collaboration and coordination are appropriate for this project, according to the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The project has identified plans for future work related to light-duty and hybrid EV operation. It also mentions three other efforts, including efforts for medium- and heavy-duty vehicles. It was difficult for the reviewer to assess the degree to which these different proposed efforts are synergistic and whether more focused plans might be desirable, given the modest size of this effort.

Reviewer 2:

The reviewer said that the proposed future work is logical and appropriate.

Reviewer 3:

The future work entails further refining the models and establishing the full operating map for the engine to leverage new materials and alloys being developed and/or to guide the development of new alloys. Further, application of this effort for hybrid EVs and medium- and heavy-duty vehicles will be explored. The reviewer opined that it would be nice to have input and collaboration with an OEM to further the applicability of the modeling effort and the validation for the use of the identified engine materials.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that the project supports the large VTO investment in materials development by providing predictive models to understand the impact of these new materials on engine performance.

Reviewer 2:

The reviewer stated that this project adequately meets the DOE objectives for minimizing fuel consumption by designing and producing engines with higher efficiencies and lightweighting.

Reviewer 3:

According to the reviewer, this project is relevant to modeling powertrain performance with different materials.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources available appeared adequate to the reviewer to support this well-focused effort.

Reviewer 2:

The reviewer commented that resources have been appropriate to address project barriers and support the approach.

Reviewer 3:

It appeared to the reviewer that the resources are sufficient to complete the work in a timely manner.

Presentation Number: mat187
Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

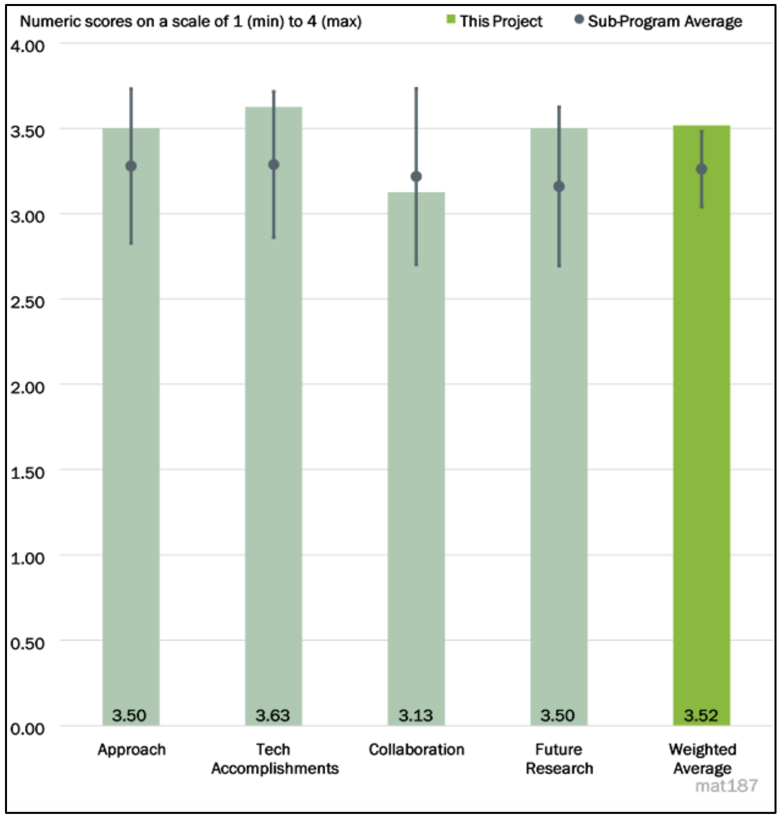

Figure 6-15 - Presentation Number: mat187 Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The researcher has a good approach to this basic research goal of understanding complex precipitation pathways in lightweight alloys. The DFT investigation of hypothesized phase transformation pathways between θ''-Al_3Cu and θ'-Al_2Cu was very interesting to the reviewer. The supercell approach for the Al matrix and Al_3Ni using high performance computing (HPC) is also a good approach.

Reviewer 2:

The reviewer found this to be an interesting opportunity to increase the temperature ranges that Al alloys are available for designs and will allow further increases in temperatures and pressures over time as these are deployed. The ability to use these alloys in components that have traditionally been cast iron is an advantage to engineers, allowing improved vehicle efficiency and safe operation.

Reviewer 3:

According to the reviewer, the project is well designed to address long-standing barriers to increasing the temperature limit of Al alloys in automotive applications. The barriers addressed include the lack of understanding associated with precipitation mechanisms and kinetics in Al alloys.

Reviewer 4:

The reviewer asserted that this is an excellent approach to identify alloys that segregate to the precipitate interface to delay transformation of theta prime to theta.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The work using the DFT database of solute partitioning in Al-copper (Cu) (A206) precipitates and DFT solute segregation database at the interface between an Al matrix and Al_3Ni has shown to be very useful to the reviewer.

Reviewer 2:

The increases in temperature for Al-Cu alloys has direct application and is a major accomplishment. The reviewer remarked that this is well planned and well executed.

The Al-Ni alloys hold promise for a large array of applications if the spheroidization is overcome. This work indicated to the reviewer that that it is possible.

Reviewer 3:

The reviewer commented that this project has completed, or is on track to deliver, all milestones in characterization and modeling of precipitation pathways.

Reviewer 4:

The reviewer observed excellent accomplishments to identify solutes that segregate to the semi-coherent interfaces to stabilize theta prime in the Al-Cu system and identify zirconium (Zr) enrichment at Al/Al_3Ni to retard coarsening in that system. What was not clear to the reviewer is how those alloying additions were identified or if it were done by DFT. It is not clear if these additives have been tried by experimentalists or if this is a first.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Good collaboration and coordination appeared evident to the reviewer, based on the quality of work presented while meeting timing milestones.

Reviewer 2:

There is good collaboration between the various national laboratories, according to the reviewer.

Reviewer 3:

The reviewer said that evidence of work between PNNL, ANL, and ORNL was presented.

Reviewer 4:

The researchers have assembled a collaboration between different national laboratories (ORNL, ANL, and PNNL) and with some industry (Fiat-Chrysler Automobiles [FCA] and Nemak), but collaboration with academia (Worcester Polytechnic Institute [WPI], etc.) on this type of basic research—such as the interface between an Al matrix and Al_3Ni—could require a Big Data (industry 4.0) type of approach. The reviewer asserted that collaboration with a data scientist on this type of basic research could help to achieve the goal in a timely manner.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Understanding the evolution of Al and Al_3Ni is a great direction. Also, the reviewer said that the idea of solute segregation at the interface has a lot of promise. Nice work has been done by the team to define the actual accomplishments and then use those to map out the next set of required data.

Reviewer 2:

The work on the construction of a DFT solute segregation database at the interface between an Al matrix and Al_3Ni is very interesting. The research team is going to determine if it is possible to mitigate detrimental spheroidization of Al_3Ni microfiber via solute segregation. The reviewer was looking forward to reading the paper on neutron diffraction analysis of deformation in a thermally stable Al alloy at room and elevated temperature.

Reviewer 3:

According to the reviewer, the project's future plan is well aligned to address barriers in lightweight alloy development with reasonable next steps building on previous accomplishments.

Reviewer 4:

It was not clear to the reviewer if the multiple solute segregation effects can be successfully handled by DFT.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that this project work in characterizing, modeling, and applying the fundamentals of precipitation kinetics to engineer new alloys is critical to DOE objectives for accelerating the development of lightweight alloys for automotive applications.

Reviewer 2:

The reviewer affirmed that, yes, either higher temperature engines or Al lightweight brake calipers will allow for more efficiency and will lower the carbon footprint of a vehicle.

Reviewer 3:

According to the reviewer, lower mass always improves vehicle efficiency, and this also has improvements in thermal conductivity.

Reviewer 4:

The reviewer found good work driving the lightweighting research.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer asserted that more resources could speed knowledge, and this is a great area to add additional resources due to its high impact.

Reviewer 2:

The reviewer stated that the project is sufficiently funded to deliver the plan.

Reviewer 3:

The reviewer noted that this type of basic research takes a lot of resources, and the project team has three national laboratories working with the team on this subject. Again, a university data scientist might be an additional resource to help arrive at the goal in a more timely manner.

Reviewer 4:

It was unclear to the reviewer whether all the work being comprehended is contributing to the outcome.

Presentation Number: mat188
Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys
Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

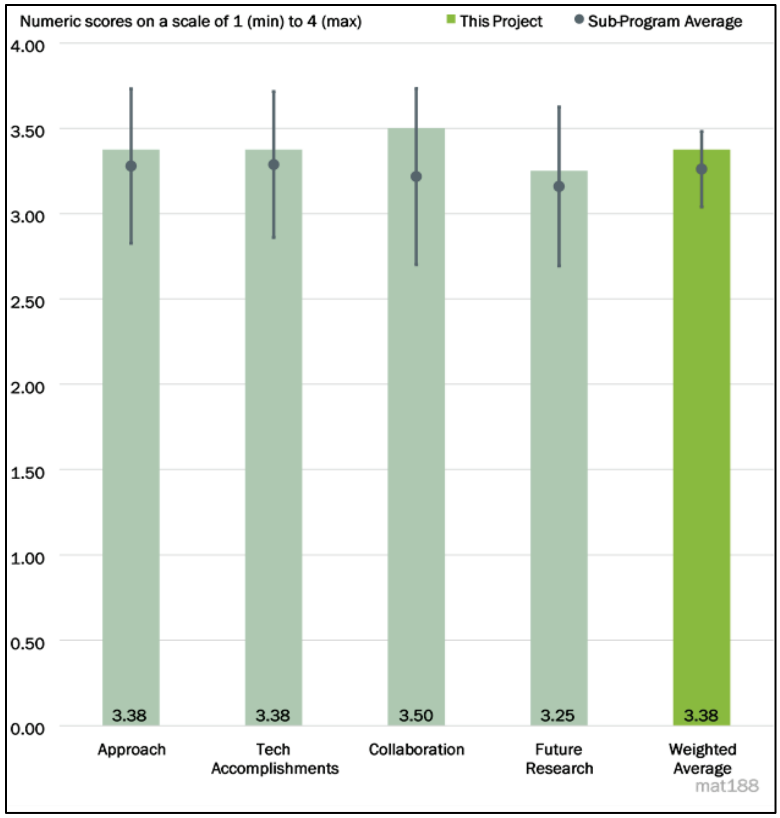

Figure 6-16 - Presentation Number: mat188 Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

Presenter

Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The premise is sound and the impact on the market would be sizeable. The reviewer opined that this is an area where changes would significantly impact the fuel efficiency of vehicles, both passenger cars as well as medium-duty commercial vehicles.

Reviewer 2:

The reviewer said that the approach has been to relate material properties of Al-Cu-Mn-Zr (ACMZ) alloys for automotive powertrain applications to the fundamental barriers of understanding microstructure kinetics.

Reviewer 3:

It is a well-designed and well-planned project, and the reviewer said that the technical barriers are addressed.

Reviewer 4:

Considering that the overall alloy system is defined, the work to understand the influence of processing on microstructure—the heart of commercialization—was not clear to the reviewer. The effect of particles and ductility is known, and the effect of porosity on fatigue is also known. How to optimize between chemistry and process is not known. It is also not clear whether solidification modeling is a part of the ICME approach.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

It is a great process to assess the microstructure options with an eye toward commercialization. This allows alloys to be well defined with all the necessary properties to be available to designers, making adaptation much quicker. According to the reviewer, the ability of the team to focus on the specific materials properties that are not yet optimized creates a strong data set for designers.

Reviewer 2:

Good accomplishments have been made to understand microstructure influence on properties, especially the work on correlating macro-strain with a theta phase lattice strain. Also, the reviewer commented that there is good work on understanding the influence of chemistry and microstructure on creep behavior.

Reviewer 3:

The reviewer remarked that the team studied properties of cast Al alloys and understood how grain boundary and strengthening precipitates affect the mechanical properties and corrosion of a series of ACMZ alloy compositions. The team produced multiple journal papers, including four in 2021 and two in 2020.

Reviewer 4:

The reviewer said that project milestones have been completed in ACMZ alloys studies in thermal stability, thermal conductivity, and creep as a function of differing compositions of alloying elements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Project collaboration by lead and partner organizations was presented as effective and positive, according to the reviewer.

Reviewer 2:

The reviewer said that there is good collaboration between the various national laboratories and Industry.

Reviewer 3:

Three national laboratories are actively participating in the planned tasks led by ORNL in partnership with ANL and PNNL. In addition, the reviewer stated that there is collaboration with GM and Northwestern University.

Reviewer 4:

The reviewer commented that the presentation explained the collaboration between ORNL, PNNL, Northwestern University, and General Motors.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted that the corrosion data will be very useful, and the ability to use these alloys in EV applications is great. The materials property data sets are of great value to both ICE and EV platforms.

Reviewer 2:

Future project attention on alloy development for EV applications is appropriate, according to the reviewer.

Reviewer 3:

Future work focuses on microstructure and thermal and electrical conductivity relationships to be co-optimized with mechanical properties. As the thermal conductivity of the alloy is often much lower than that of pure metal, the relationships between the thermal conductivity of Al and contents of alloying elements, as well as temperature, need to be studied systematically. Therefore, the reviewer asserted that the ways to achieve the optimal compromise between the strength and electrical and thermal conductivity need to be studied systematically.

Reviewer 4:

Key issues for correlating casting processing to microstructure appears generalized under the term "commercialization." The other application for EVs appears incomplete in terms of what these new alloys will provide. The application on brakes includes composites, and the reviewer was not sure how these connect.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

As stated, the reviewer found that this is an excellent advancement in materials that will lead to more efficient vehicles due to reduced mass and longer lives.

Reviewer 2:

The reviewer commented that accelerating alloy development with ICME to deliver targeted, in-service performance metrics is a definitive need for the automotive industry.

Reviewer 3:

According to the reviewer, the project is well aligned with the overall DOE objectives as it plans to develop more robust engine materials that can withstand higher temperatures and combustion pressures, and thus enable higher efficiency powertrains.

Reviewer 4:

The reviewer said that improving elevated temperature and fatigue properties of Al is a good goal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Progress seems to be moving at a good pace and all seem to be contributing. The reviewer emphasized this is nice work.

Reviewer 2:

The reviewer observed that the team has sufficient resources to carry out the planned tasks.

Reviewer 3:

Resources appeared to the reviewer to be aligned with milestone objectives.

Reviewer 4:

The reviewer was not clear if all the work being comprehended is focused on commercializing.

Presentation Number: mat189
Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing
Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory)

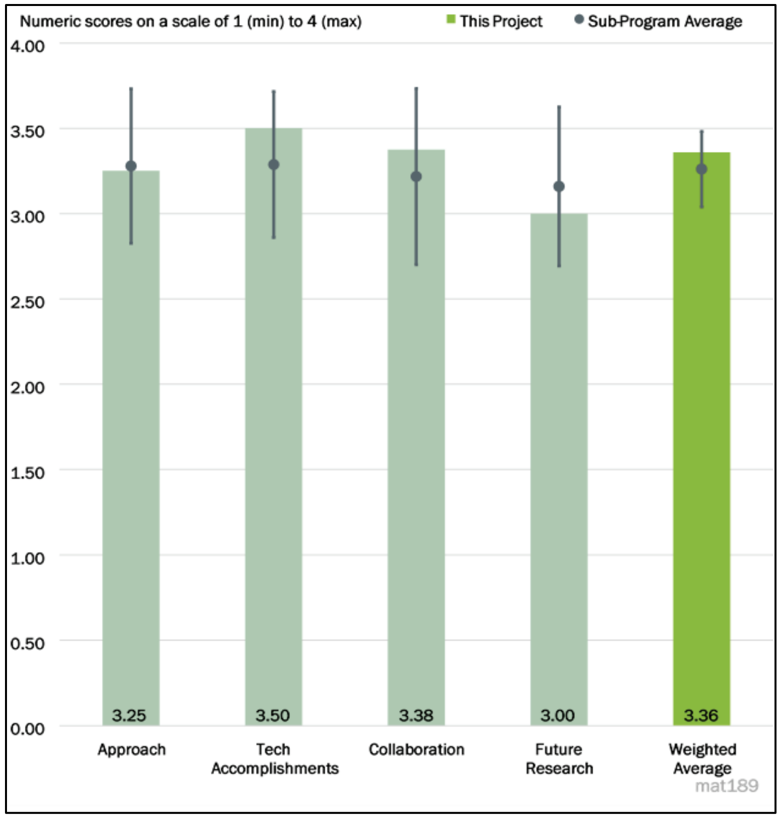

Figure 6-17 - Presentation Number: mat189 Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory)

Presenter

Alex Plotkowski, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that the approach taken here is well thought out. The combination of thermodynamic modeling with high throughput testing of different printing parameters is great.

Reviewer 2:

The reviewer said that the approach leverages ICME methods, advanced characterization, and property testing to accelerate the design of new Al alloys for AM. The alloy design is being guided by the needs to address manufacturing challenges and property requirements associated with higher power density engines. The property targets are driven by specific applications and industry partners. The effort is considering multiple alloy systems in parallel with an approach that has demonstrated feasibility.

Reviewer 3:

Excellent structures approach combining ICME, computational thermodynamics, and process testing to guide the alloy development. However, the reviewer had a concern that the lack of demonstration on shaped parts that emulate a prototype powertrain component leaves the project vulnerable to unfortunate surprises in the last year.

Reviewer 4:

The reviewer was impressed with the fast pace of the work combining different expertise in the study of a novel process and novel structures. This is an important scientific study. The points below are for consideration:

- The property requirements are not well described in this study. It may be that they are application driven but development of an alloy for better creep, fatigue, etc., will not go far toward a performance AM alloy for commercialization. At least it needs to be identified whether the application is an engine block or a cylinder head; these have different service conditions, and the requirements for fatigue are different (low cycle versus high cycle). The reviewer thought that the PI and the collaborators should have a discussion on these.
- AM microstructures are heterogeneous. A good study on the heterogeneity of the structure (grain, texture, and microstructure) needs to be included (not just the good things about the microstructure but its limitations as well).
- The creep test with a step-change in stress may not give a good indication of creep mechanisms. The microstructure evolves in the previous step. The creep mechanisms are likely dislocation creep in the service conditions studied (they would not be always influenced by grain size but would be with prolonged holding under stress, which may not be representative of the service cycles). The creep mechanisms need to be studied (activation energy determination followed by transmission electron microscopy [TEM] studies), perhaps with academia.
- There are so many alloys being developed. The reviewer suggested an ML-based study into all these data (with supervised knowledge and with training data) to optimize the alloy compositions (even with the Zr-bearing alloy) before embarking on extensive studies on AM.
- Finally, the application of these alloys is shrinking with the electrification of the vehicles. They are still important for some applications, but these continuing applications need to be explained in the study.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The work appeared to be on target to the reviewer. The key performance indicators were not defined in detail, but new alloys with improved properties for the intended applications have been developed. These alloys have demonstrated improved properties relative to current SOA.

Reviewer 2:

This reviewer observed strong efforts on AlCuCeZr and AlCeNiMn. The focus on mechanical properties, heat treatment to modify the microstructure, creep resistance, and fatigue capacity all address the critical needs for the project.

Reviewer 3:

The success in this project is quite impressive. The performance of the new alloys after printing is excellent. The reviewer suggested that one thing the project team should keep in mind for future presentations is that the good fatigue performance is only after surface machining. The team should test the fatigue performance of as-printed surfaces.

Reviewer 4:

Two of the milestones have been completed, and the third (AM structure study) is underway. The progress is normal, but the reviewer would have liked to see more in-depth study of the AM microstructures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the project leverages an extensive number of collaborations, spanning academic groups to industry. The former brings enhanced capabilities in microstructure characterization and creep testing. The latter includes a cooperative research and development agreement (CRADA) with GM for applications in medium-duty truck piston design, as well as key partnerships for feedstock production.

Reviewer 2:

The collaborations are directly contributing to the success of the project, and the coordination seemed good to the reviewer.

Reviewer 3:

The strong accomplishments indicate good coordination and cooperation across the project participants and contributors. The reviewer would have liked to see a chart or table illuminating the typical interactions (i.e., weekly, monthly, and/or quarterly) and a clear list of roles and responsibilities, plus a "gives and gets" table showing the interactions as the project continues.

Reviewer 4:

The tasks of the various parties are mentioned but a description of the nature of the collaboration (virtual meetings, their frequency, and a perhaps a short summary input from the collaborators) would have been interesting to the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The work to date has demonstrated opportunities for achieving improved properties through the production of novel, non-equilibrium microstructures produced by AM. The reviewer said that to fully exploit these opportunities, an effort will be devoted to understanding more fully these non-equilibrium microstructures. Advancing fundamental understanding along these lines will be key to guiding alloy design to exploit such opportunities going forward.

Reviewer 2:

The plans are reasonable to the reviewer and address the remaining barriers.

Reviewer 3:

The reviewer said that some of the comments in the answer to Question 1 should be considered as a response to this question.

Reviewer 4:

The proposed work culminates in a prototype component. The reviewer had concerns that a shaped component has not been attempted or at least reported to date. The development, demonstration, and testing of a prototype part is a critical portion to have these new materials accepted by industry. Also, the lack of a powder supplier to address any powder production challenges might be a hole in getting these new materials into automotive parts.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The project supports the development of new alloys that can be produced by AM. This approach provides new design opportunities for improving engine performance and fuel economy. The unique microstructures produced by this processing route provide opportunities for producing materials with improved properties and performance. The reviewer noted that several challenges exist in the application of existing commercial alloys that this project is addressing through new alloy design.

Reviewer 2:

Better materials for powertrain components can improve efficiency and thus reduce energy consumption. According to the reviewer, the use of these new materials in 3-D printing and AM can enable unique designs to further improve high-temperature efficiency.

Reviewer 3:

The reviewer found the work to be highly relevant.

Reviewer 4:

This reviewer stated yes, and referenced prior comments that should be addressed to better evaluate relevance.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources appeared to the reviewer to be sufficient, as the project is productive and on track.

Reviewer 2:

Resources are sufficient, but the reviewer suggested that some allocation should be made to further the study of creep mechanisms and an ML-based optimization of the alloys.

Reviewer 3:

The reviewer found that the funding is sufficient.

Reviewer 4:

The resources are sufficient for the project scope, according to the reviewer.

Presentation Number: mat190
Presentation Title: Oxidation Resistant Valve Alloys
Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

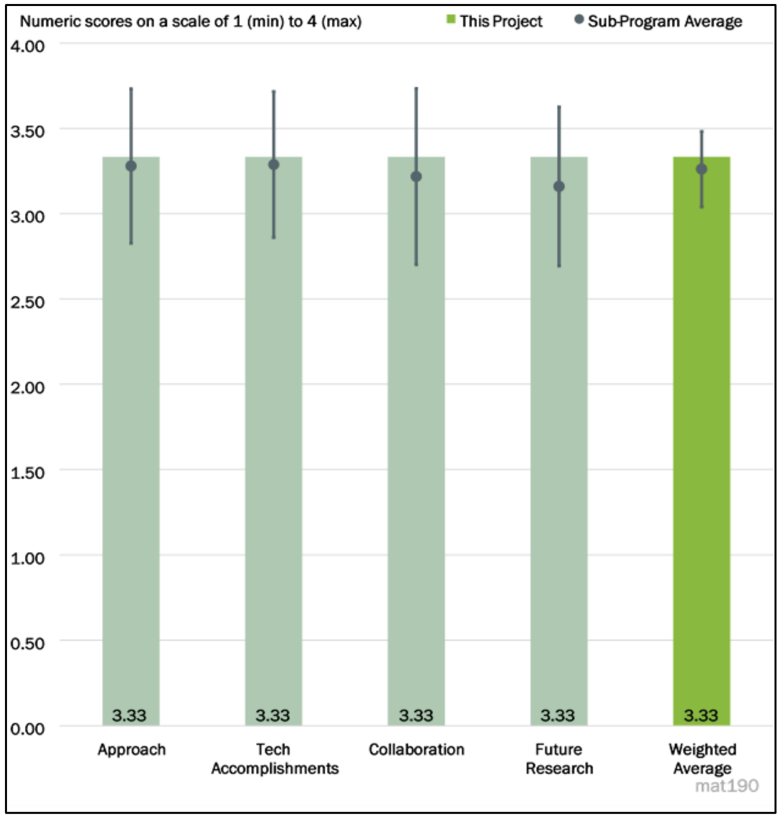

Figure 6-18 - Presentation Number: mat190 Presentation Title: Oxidation Resistant Valve Alloys Principal Investigator: G. Muralidharan (Oak Ridge National Laboratory)

Presenter

G. Muralidharan, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that the team's overall approach is excellent, and the researchers are addressing important barriers.

Reviewer 2:

The project shows a well-organized plan to evaluate high-temperature performance of newly developed chromia-forming and alumina-forming alloys. The reviewer found that the proposed tasks are adequate to address the barriers.

Reviewer 3:

Generally, the researchers present a structured and concise approach to performing and achieving the project targets. The reviewer suggested that some further explanation of the exact property requirements for valve alloys could be made and the link to the work performed could be more clearly drawn. Additionally, a detailed justification of the alloy choice for scale-up would be helpful.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress is excellent. The performance of the researchers' latest alloy is very impressive. The reviewer was very happy to see that the team plans to create an actual valve and test it in an engine.

Reviewer 2:

Based on the technical objectives outlined, the reviewer commented that there is good agreement with the results obtained.

Reviewer 3:

Alloy 6B-alumina shows promising results (high-temperature strength and superior oxidation resistance). The high-temperature fatigue test is planned to evaluate its performance. The reviewer suggested that detailed microstructure characterization, specifically for precipitates, should be included to understand why it performs better when compared with others.

Most results shown are heavy on performance indexes, which is understandable. The reviewer was not sure if they were from a single heat or multiple heats. The properties should be verified after scale-up production. It is also not clear if the alloys can be used in the as-cast condition or if additional heat treatment is needed to achieve the desirable microstructure.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, collaboration among project team members is well coordinated.

Reviewer 2:

The reviewer noted that there does seem to be good collaboration among the team.

Reviewer 3:

From the presentation, it seemed to the reviewer that the majority of the work is being done at ORNL and that the collaborations are on the periphery and are not part of the main work of the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer observed that the proposed future work is reasonable and directly addresses the remaining barriers.

Reviewer 2:

The reviewer indicated that the proposed future tasks are adequate to finish the proposed project.

Reviewer 3:

The proposed upscaling strategy appears to be sound in itself. The reviewer asserted that a clear rationale for the exact choice of alloy compositions should be given.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer asserted that this project certainly supports the objective for energy efficiency in transportation.

Reviewer 2:

The project directly addresses DOE goals and objectives, according to the reviewer.

Reviewer 3:

Development of high-temperature alloys has been important in improving the efficiency of the engine, especially for vehicles equipped with ICEs. The reviewer opined that the focus may shift away in the years to come as the nation moves toward EVs.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources for the project are sufficient.

Reviewer 2:

No shortage of resources was communicated to the reviewer.

Reviewer 3:

The funding is reasonable to the reviewer.

Presentation Number: mat191
Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program
Principal Investigator: Tom Watkins (Oak Ridge National Laboratory)

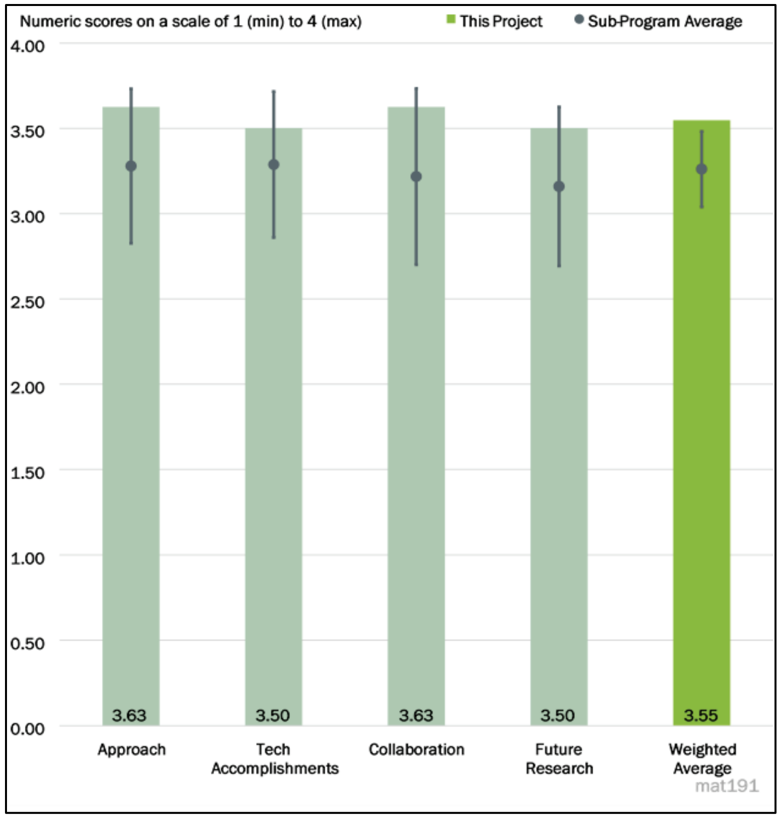

Figure 6-19 - Presentation Number: mat191 Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program Principal Investigator: Tom Watkins (Oak Ridge National Laboratory)

Presenter

Tom Watkins, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The details provided by the presenter showed an excellent insight into the characterization techniques utilized in this program. State-of-the-art microscopy was presented that provided a valuable source of information to interpret various results collected as part of this project. In particular, the reviewer found that the atom probe tomography (APT) of oxidation along grain boundaries was particularly impressive.

Reviewer 2:

This reviewer identified Research Thrust Area 4A – Advanced Characterization within the Powertrain Materials Core Program under the Powertrain Materials Core Program (PMCP). The reviewer said that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to use to leverage limited resources and investigate several potential solutions. This project provides the characterization of 24 different projects. The consolidated approach leverages synergies between projects.

Reviewer 3:

The approach makes use of SOA characterization tools available in the DOE scientific user facilities to advance understanding of microstructure of materials being developed across the three thrusts of the PMCP. The tools are expertly used, and important insights have been gained to support material development efforts.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted that the task start was October 2018, and the task end is September 2023. The project is on target for completion in September 2023 and is 50% complete. The budget in FY 2020 was $1.05 million, and the budget in FY 2021 was $1.02 million. This averages out to approximately $45,000 per year for each project.

The reviewer highlighted several excellent results below:

- Cast ACMZ alloys for engine heads: Properties are controlled by precipitates. Theta prime is beneficial, but theta is deleterious in cast structure. It was determined that (AM of the same alloy produces a unique, fine microstructure where properties of AM are much better than that of cast. This is an excellent result. Also, dispersed fine theta precipitates were stronger and stiffer than theta prime, which both strengthens and increases ductility in the ACMZ alloys. This is another excellent result.
- Regarding investigation of new alloys that can work within the increasing operating temperatures and pressures of advanced ICEs, new alloys are needed because existing alloys have poor strength and corrosion resistance at higher temperatures (greater than 870°C). The research team was able to identify a unique outcome that will enable key future studies of oxygen solubility in more complex alloys using electron backscatter diffraction (EBSD), an excellent result.

Reviewer 2:

The reviewer found that good progress was demonstrated across the different thrusts. New insights were derived using advanced characterization techniques related to structure-property links in AM lightweight alloys, high-temperature oxidation processes, and microstructure in advanced high-strength steels.

Reviewer 3:

The reviewer said that the work is very good; in particular, the atom probe was utilized in a very effective way.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that materials characterization within such a project always serves a multidisciplinary role. As apparent from the presentation, there is excellent collaboration among the team.

Reviewer 2:

Laboratory personnel (ORNL, PNNL, and ANL) leverage specialty equipment to efficiently assess and characterize materials. Microscopy and modelers also work closely together. The reviewer remarked that coordination with ICME includes weekly meetings and discussion of the latest results.

Reviewer 3:

This project involves three national laboratory partners, and evidence was shown of coordination across these laboratories in response to last year's reviewer comments. It was difficult for the reviewer to assess the degree to which there is direct collaboration and coordination between the efforts of this project and the extensive characterization efforts taking place within the different Thrust 1-3 PMCP projects, many of which demonstrated in presentations detailed characterization work in the context of alloy design. Also, it was unclear if there is coordination across techniques (e.g., advancing correlated characterization approaches in this context).

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The outlined future work seemed appropriate to the reviewer.

Reviewer 2:

The project supports a wide breadth of research spanning the different thrusts in the PMCP program. Hence, it would be helpful to the reviewer to understand how the priorities for future work are selected. Presumably, these priorities are set by key bottlenecks in materials development efforts that require insight into structure-property links beyond what can be derived from more routine characterization efforts already included in Thrusts 1-3 projects. Time on the user facilities is limited so prioritization of the most impactful areas where advanced characterization is needed seems important. More discussion of how these priorities are set would be helpful for future reviews.

Reviewer 3:

This reviewer reported the study of microstructural features to understand the co-optimization of material properties, and observed a cost-effective approach to develop materials properties quickly. Also, the reviewer listed plans to use the equipment in a manner that will produce the intended results. Planned activities include STEM and APT at nano scale and atomic scale at ORNL and PNNL--structure, composition, shape, size, and size distributions; high-strength Ni-based super alloys; carbides in AM austenitic steel; and AFA alloys—as well as diffraction, small angle x-ray scattering bulk view at nano scale via ANL Synchrotron—phase, distribution, sizes; Ni-based alloys; AFA alloys; and in situ coarsening behavior in advanced martensitic steels. The reviewer also highlighted electrical and thermal measurements for EV materials and neutron in situ creep of precipitate strengthened ACMZ alloys at ORNL.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles. Also, it involves researching materials to improve electric-powered vehicles.

Reviewer 2:

The reviewer commented that project supports materials development efforts across PMCP thrusts.

Reviewer 3:

According to the reviewer, the overall objectives of the project help to improve fuel efficiency in transportation vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

This project has substantial resources, and the work appears to be on track. The reviewer said that it is impressive to see the progress made even in the face of the pandemic, which must have severely limited access time to the user facilities.

Reviewer 2:

The reviewer observed that this project is on schedule and the funding appears to be sufficient because all the stated milestones have been completed on time (to date).

Reviewer 3:

The reviewer noted that no shortages in the budget were reported.

Presentation Number: mat192
Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing
Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

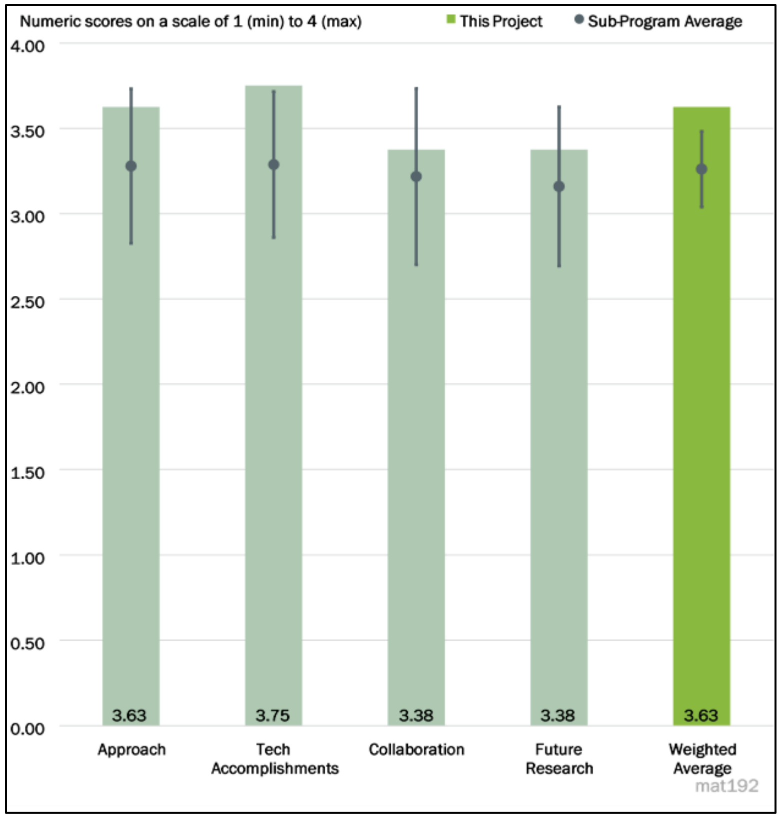

Figure 6-20 - Presentation Number: mat192 Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

Presenter

Sebastien Dryepondt, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that this work couples state-of-the-art modeling techniques with novel processing routes (AM here) to develop new, high-performance alloy systems. Both the topic as well as the approach are therefore outstanding. The project is thoroughly carried out. Due to the excellent results achieved, an expansion of the application could be anticipated.

Reviewer 2:

The reviewer asserted that the approach fully supports and addresses the technical barriers identified in the beginning of the presentation. These are specific technical targets in the DOE VTO Propulsion Materials area and are part of the U.S. DRIVE roadmap strategy. The approach is consistent with routine materials development projects that start with commercial metals or fully developed metals and looks at using AM to optimize their fabrication. It also includes advanced characterization of structures and physical property testing.

Reviewer 3:

It is a well-designed and well-planned project, and the technical barriers are addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer indicated that technical accomplishments for FY 2021 focus on a laser powder bed fusion (LPBF)method for fabricating austenitic steels, which was demonstrated to provide superior strength over commercial alloys. It also provided similar oxidation resistance because their unique and specific cellular structure was fabricated with AM. Analysis of the microstructure confirmed the strengthening feature for two different alloys. These are excellent results for the materials being characterized. Good results for stress reduction were also obtained from the annealing experiments and for the predicted microstructure that was validated with experimental results. Although the project began in FY 2019, only the FY 2021 milestones are addressed and are shown to be completed or on track to complete. The reviewer praised this research as outstanding for the resources involved.

Reviewer 2:

The reviewer emphasized that the results collected so far are excellent.

Reviewer 3:

The reviewer noted that the team conducted tensile testing at a range of temperatures on the CF8C+ steel fabricated by LPBF and demonstrated that carbonitride nanoscale precipitates at less than 100 nanometers (nm) in size. The team produced three journal papers, including two under submission.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration and coordination are primarily between two national laboratories for the materials preparation and characterization. One university and an AM developer are the other partners, which rounds out the team for early-stage research support and for advanced development assistance once the technology is mature. There is not a materials supplier or OEM involved, so the reviewer warned that technology transfer will only occur to the AM developer who would then be a Tier 1 supplier.

Reviewer 2:

The collaboration within the project team appeared good to the reviewer.

Reviewer 3:

The reviewer said that the team is led by ORNL and is partnering with PNNL, Pennsylvania State University, and Siemens.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer indicated that the team plans to develop, produce, characterize AM-specific high-temperature high-strength alloys. Additionally, the team plans to do in situ testing, crystal plasticity, and finite element method (FEM) modeling by using advanced characterization and data analytics to improve understanding of the formation, role, and stability of cell structure.

Reviewer 2:

The proposed future research appears to be an extension of the existing research, i.e., to develop and characterize more alloys and to perform advanced characterization and data analytics. The “new” research is to conduct testing and modeling to better understand the formation, role, and stability of the cell structure. The reviewer asserted that this has the potential to optimize the alloy structure and optimize the AM method for these materials.

Reviewer 3:

The reviewer has no objections to the proposed future work.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project directly supports the overall DOE VTO technical targets for materials development and the U.S. DRIVE roadmap strategy for advanced material development of high-performance materials used at elevated temperatures in automotive powertrains fabricated with advanced manufacturing process methods.

Reviewer 2:

The reviewer noted that high-performance alloys allow higher efficiencies in transportation applications.

Reviewer 3:

The reviewer said that the proposed tasks are well aligned with the overall DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The funding is about $200,000 per year, which is sufficient for material development, characterization, analysis of the new alloy compositions fabricated by additive manufacturing, and the modeling effort. The reviewer found that the number of researchers and collaborators are adequate for each technical area being addressed.

Reviewer 2:

The reviewer stated that the team has sufficient resources to carry out the planned tasks.

Reviewer 3:

No insufficiency was reported by the reviewer.

Presentation Number: mat193
Presentation Title: Higher Temperature Heavy-Duty Piston Alloys
Principal Investigator: Dean Pierce (Oak Ridge National Laboratory)

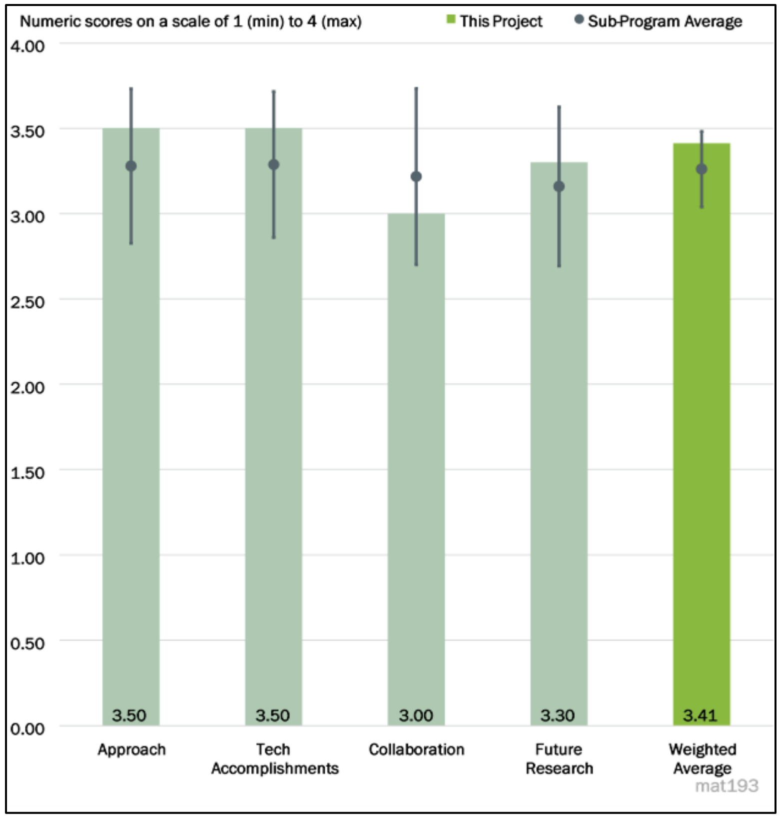

Figure 6-21 - Presentation Number: mat193 Presentation Title: Higher Temperature Heavy-Duty Piston Alloys Principal Investigator: Dean Pierce (Oak Ridge National Laboratory)

Presenter

Dean Pierce, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The results were presented in a very clear fashion. The approach taken in this project appeared sound to the reviewer, who suggested that it would be wise to also include creep resistance and fatigue testing.

Reviewer 2:

The reviewer said that the approach is reasonable and would lead to reaching milestones and objectives of the project.

Reviewer 3:

The reviewer stated that this project has a good approach. The use of the commercial alloys to quantify the improvements from the given alloys is a great part of the approach. Also, the development of three different alloys (with different Cr compositions) is very nice, as it allows the team to provide a range of possibilities for future pistons. The presenter mentioned that the team hoped to make prototype valves from the alloys, but that depends on finding an industry partner. The reviewer emphasized that making prototype pistons is very important in proving that the alloys can be applied, so this should be strongly prioritized.

Reviewer 4:

The reviewer identified Research Thrust Area 2A2 – HD Diesel piston materials under the Powertrain Materials Core Program (PMCP) and stated that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to use to leverage limited resources and investigate several potential solutions. This project is assessing higher temperature heavy duty piston alloys for compression ignition engines.

According to the reviewer, ORNL is investigating three martensitic steel concepts for piston material in heavy-duty vehicle applications. The baseline are three alloys—4140 alloy plus two 12 Cr martensitic steels. Development alloys are low Cr (0-3 wt.%), medium Cr (3-8 wt.%), and high (8-15 wt.%). The increase in Cr is linked to oxidation resistance. Researchers are targeting high-performance, low material cost, and high manufacturability. The reviewer also noted significantly accelerated alloy development time using reasonably priced raw materials.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that the performance of the three ORNL alloys is very impressive. The research team has achieved goals very effectively.

Reviewer 2:

The reviewer noted that the alloys being tested show promise, although cost-benefit analyses are lacking at this point. The reviewer presumed that will come soon as the project enters its final half.

Reviewer 3:

The reviewer said that there appears to be excellent progress in meeting the objectives of the project.

Reviewer 4:

The reviewer listed the achievements of this project regarding Cr alloys:

- ORNL low-Cr developmental alloys have a100% Increase in strength at 600°C and a 10% increase in thermal conductivity versus the alloy 4140.
- Medium-Cr alloys achieve an oxidation resistance similar to 12Cr steels at lower costs. A 200°C increase in oxidation for ORNL-D is a very low mass change. There is a slightly higher cost, but oxidation improvement is exceptional.
- High-Cr alloys overcome the tradeoff between strength, thermal conductivity, and oxidation. Significant increases in peak surface temperature occur above the strength limit of the alloy. High-Cr alloys result in lower thermal conductivity (25°–30°C in surface temperature) and improved durability of the piston. This results in a decrease of oil cooling loads and parasitic losses for engine efficiency.
- Results after 150 and 422 hours significantly increase oxidation masking. New ORNL G and H alloys performed very well up to 700 hours, successfully decoupling the performance criteria from the Cr weight percentage.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, there is excellent collaboration within the project team.

Reviewer 2:

The reviewer found that the collaborations outside the laboratory are complex and well positioned to validate the results.

Reviewer 3:

The researchers are partnering with ANL under Thrust 4A: Advanced Characterization, Advanced Photon Source. The project is loosely associated with the U.S. Army Ground Vehicles Systems Center (GVSC). The reviewer remarked that the team is still exploring potential industry partnerships to commercialize the 600°–650°C piston material.

Reviewer 4:

Collaborations were briefly mentioned but none of the presented results seemed to the reviewer to use any of the capabilities from the collaborators.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer commented that future work is reasonable and will contribute toward meeting milestones and goals. Cost-benefit analyses, which the PIs say are going on in other thrusts, will be essential for a successful drive toward commercialization.

Reviewer 2:

The reviewer said that the proposed future work meets the reviewer´s agreement.

Reviewer 3:

This reviewer reported accelerating alloy development time and improving the balance of elevated – interesting co optimization problem. Planned end date remains September 2023.

The reviewer commented that proposed future research for FY 2022 and beyond includes performing remaining optimization of developmental alloys prior to scale up (6–12 months); initiating partnerships to scale up material for prototype piston manufacturing with supplier; and identifying opportunities in the EV space for application.

Reviewer 4:

The future plans were reasonable to the reviewer. The reviewer’s one worry is the lack of a definitive plan for the creation of prototype pistons. The prototype is a critical part of proving the successful of these alloys targeted at a specific application.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports the overall DOE objectives by providing the knowledge needed to develop high-performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 2:

Higher temperature alloys would lead to higher operating engine temperatures. The reviewer asserted that this would lead to higher efficiency and more durable engines.

Reviewer 3:

According to the reviewer, the measures investigated provide means to improve the fuel efficiency of vehicles.

Reviewer 4:

The work is highly relevant to the reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

This project is on schedule and the funding appears to be sufficient because all the stated milestones have been completed on time (to date). Through collaboration, the reviewer noted that the team avoided duplicate research and additional cost.

Reviewer 2:

The team seemed to the reviewer to have sufficient resources. Data on spend rate (ratio of amount of work done to dollar spent) would be a helpful gauge to help determine whether money is sufficient or not.

Reviewer 3:

The reviewer indicated that resources are sufficient.

Reviewer 4:

The reviewer said that no lack of resources was reported.

Presentation Number: mat195
Presentation Title: Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks
Principal Investigator: Brian Knouff (Oak Ridge National Laboratory)

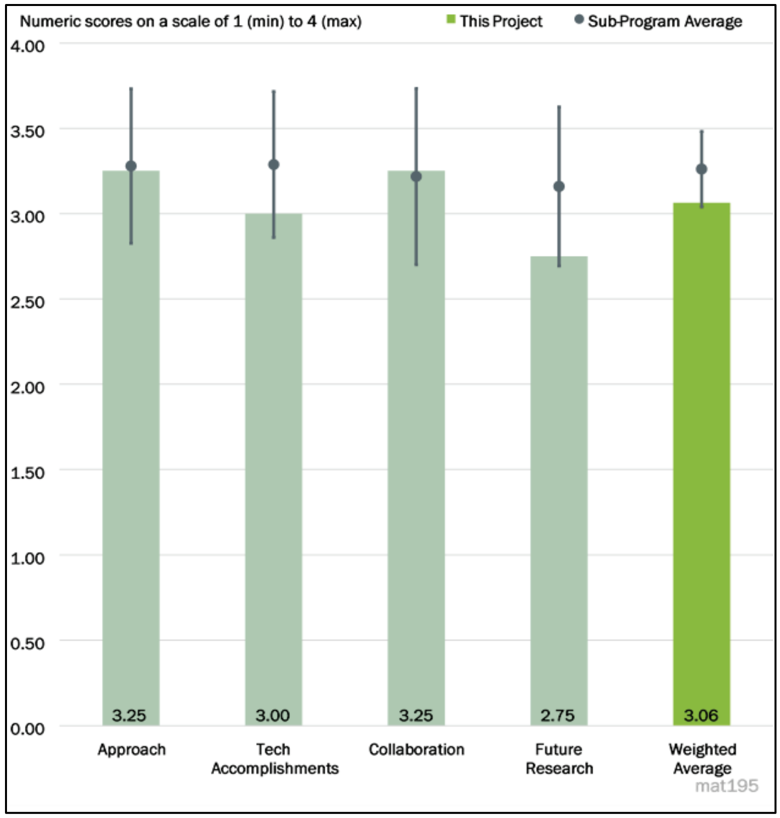

Figure 6-22 - Presentation Number: mat195 Presentation Title: Industrialization of Carbon Fiber Composite Wheels for Automobiles and Trucks Principal Investigator: Brian Knouff (Oak Ridge National Laboratory)

Presenter

Brian Knouff, Oak Ridge National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The technical approach is solid, but the project is behind due to a laboratory shutdown. The work will be extended 6 months for the environmental testing. The proposed Year 2 change to develop AM tooling seems out of scope for the original work. It seemed to the reviewer that there could be additional work to improve the wheel performance and material process controls for improved quality.

Reviewer 2:

The project is considering a tailored fiber placement (TFP) process for the carbon wheels application. The team is witnessing reduced in-plane tensile strength due to the stitching process. The project is devised around a test matrix to characterize the properties at room and elevated temperatures. Researchers are looking at a printed metal AM tool and resin infusion with layup of TFP layers. Overall, the approach to performing the work was reasonable to the reviewer. Some of the process aspects of the AM tool and anticipated issues in maintaining the geometric tolerance may pose a challenge, but the project may provide answers as it proceeds. The 6-month delay due to COVID-19 has put the project behind.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The team has made great progress considering the limitations and challenges with laboratory shutdowns. The team identified stitching as the key contributor to the tensile strength and is working to address alternative ways to deal with that impact. The reviewer stated that there is nice work on the TFP work for setting up the panel testing for tensile and flexural data.

Reviewer 2:

It appears that the 6-month delay due to COVID-19 has impacted the technical deliverables. The current phase of the project pointed to making some TFP laminates and conducting flex and ILSS tests. A significant amount of characterization work needs to happen prior to the next steps of design and prototype development. It was not clear to the reviewer from Slides 13–15 if this were prior work at ESE Carbon that the current material systems will progress toward. Also, the additional information in terms of modeling and tooling development was not clear about whether that was current work or building from past work. The project needs to align carefully with the technical milestones that were proposed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer said that the team work on the material testing, wheel design, and evaluation was great. A significant weight reduction was achieved over an Al wheel.

Reviewer 2:

ORNL is collaborating with ESE Carbon. That was clear from the briefing. The slides titled "Collaborator" (Slides 13–15) gave the information on the ESE Carbon technology but did not provide any insight into the specific nature of the collaboration. Hence, it was not possible for the reviewer to assess the specifics of the collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Despite the team's progress, the reviewer stated that the testing is lagging due to issues at the beginning of the project beyond the team's control. The proposed work is addressing the barriers and the environmental testing that still need to be completed.

Reviewer 2:

The proposed "Future Research" on Slide 17 was somewhat vague and not fully thought through. Future research points to only metal AM tooling aspects. Without any early work on the AM tool, how can the team start making improvements on future work? For example, the ideas to allow fluid channels, eliminate the computer numerical control (CNC) roughing step, eliminate the hole drilling step, reduce parts by 50%, and achieve time savings of 50% are overarching, broad brush statements that really do not convey anything specific. The reviewer stated that no mention of tooling materials, composition, response to temperature, etc., has been considered.

Also, future work should have included the team's outlook on materials response, optimization of the TFP preform, what the current shortcomings are, how they will be overcome, etc. The work thus far has limited scientific backing. The reviewer asserted that some deeper science backing the rationale for the study and the mechanics and mechanisms would have helped.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The weight reduction of 40% as well as increased wheel performance is a win-win, and the reviewer asserted that the team should receive kudos for the demonstration.

Reviewer 2:

Lightweighting technologies directly benefit weight- and energy-saving goals. The reviewer indicated that the use of a domestic CF supply will advance the U.S. position in advanced materials and manufacturing.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, the team has demonstrated and performed well, despite the challenges, and has met milestones and targets.

Reviewer 2:

The reviewer stated that the team has the necessary resources. AM metal printing is advanced technology at ORNL, and ESE Carbon has the wheel technology.

Presentation Number: mat196
Presentation Title: High Temperature Carbon Fiber Carbonization via Electromagnetic Power
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

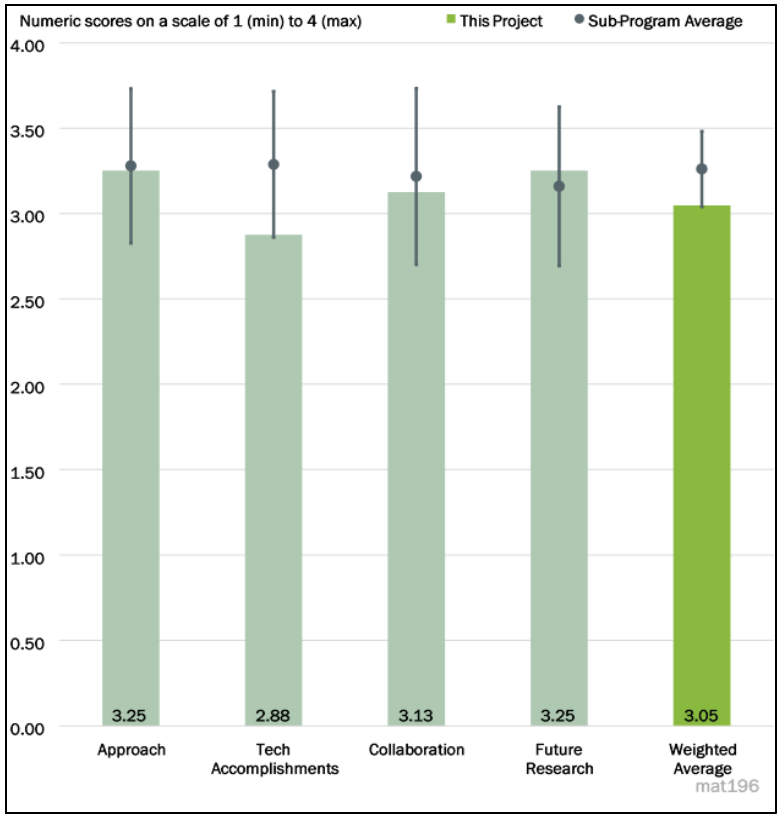

Figure 6-23 - Presentation Number: mat196 Presentation Title: High Temperature Carbon Fiber Carbonization via Electromagnetic Power Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter

Felix Paulauskas, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer remarked that the development of the two-stage, high-temperature carbonization procedure to reduce the energy and therefore the cost of producing CF is the logical next step in this long journey to increase the use of CF in the automotive industry. The strategic approach to develop a process that directly coupled energy from a source to the fiber through electromagnetic coupling is creative and possibly a 5% cost reduction.

Reviewer 2:

The approach seems generally sound. The work is still in its early stages, and the reviewer stated that how the approach is executed as well as the ensuing results will go a long way in validating the approach.

Reviewer 3:

The technical barrier was limited on the low-temperature carbonization (LTC) and this project is moving to a high-temperature (HTC) process and has utilized modeling to design the parameters needed for success. The approach was practical and feasible to the reviewer.

Reviewer 4:

The reviewer stated that this project deals with HTC via dielectric heating. The team approaches it in that the dielectric heating is faster and more efficient than conventional and can be conducted at atmospheric pressure. In the team's prior work, researchers focused on LTC with the current technology. In this work, the team is focused on HTC. The scientific approach seemed reasonable to the reviewer. The emphasis is on energy savings, although the relation of the technical approach to how energy savings would be achieved was not entirely clear from the briefing beyond the fact that density differences occur with a short versus long process. How that impacts energy was not clear to this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The technical and project management accomplishments are excellent, especially through the COVID-19 challenges of 2020 and early 2021. The design of the equipment is based on solid physics. The reviewer said that the initiation of procurement of the long lead time equipment is wise to keep the project on track for success.

Reviewer 2:

Progress on the project is good, considering that the COVID-19 global pandemic caused a slowdown in the work. The September 30 go/no-go decision point is fast approaching, and the reviewer wondered whether the PIs will be able to meet this deadline due to the time lost to COVID-19.

Reviewer 3:

The project has some long lead times and has had difficulty in getting contracts in place. The modeling aspect is complete, but the milestone was not met. Lots of work in building capability and modifying the former LTC system is needed. The project has only been in place for 6 months at the time of the presentation and 4 months when presentations were submitted. The reviewer would not have expected a lot of technical accomplishments other than modeling, which was completed. The project will be a year before fiber gets put through the system.

Reviewer 4:

This project is in its early stages, so it was hard for the reviewer to assess its progress yet. It was obvious that the research team was going to expand on the lessons learned in the LTC work toward the HTC development. Also, the team proposes to use composite epoxy material (CEM) to establish the design methodology (by the way, CEM was never expanded in the slides). Slide 8 on the CEM is an important one, but it did not comprehensively convey to the reviewer the interpretation of the "Reflection" study for a given design (parameter sweep) and its relevance to the energy-savings metrics.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

ORNL is continuing to collaborate with 4XTechnologies, building upon their work on the LTC developments. The reviewer commented that this is a logical collaboration.

Reviewer 2:

The roles and responsibilities of ORNL and 4XTechnologies are clear. This reviewer would have liked to see a chart of typical interactions (i.e., weekly, monthly, and/or quarterly). The installation and commissioning of the new equipment should be explained in more detail.

Reviewer 3:

The reviewer noted that there seems to be synergy between ORNL and 4X Technologies. The PIs mention joint development including equipment construction and experimental work performed on the 4XTechnologies site. However, the relative amount of work being carried out by each organization was not explained in more detail. This would be nice for future presentations (please mention the specific contributions made).

Reviewer 4:

The presenter needs to better communicate the role and importance of 4XTechnologies. It was not clear to the reviewer how much is ORNL's and the collaborator's portion for the respective levels of effort.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The research team's immediate future work will focus on design, construction, and testing. A large amount of effort will focus on completing the CEM modeling study for an optimized design, parts upgrade, and setting up for the fiber production. Overall, the reviewer said that the future research is along logical lines.

Reviewer 2:

The FY 2021 efforts on the design of the process and equipment and then the building, installation, commissioning, and start of operations is a great plan. The reviewer warned that it might be aggressive against the proposed timing.

Reviewer 3:

The proposed work is consistent with meeting the milestone. The speed at which the work can be completed in order to meet the September 30 go/no-go decision point was more of a concern to the reviewer. Perhaps that decision point needs to be postponed.

Reviewer 4:

The proposed future research is a lot of design and build. The reviewer asserted that there are no clear decision points to measure progress of the design and build to make sure it is on track to meet milestones and commissioning.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Lowering the amount of energy used in CF production will lead to low embodied energy of CF composites, which the reviewer said aligns directly with DOE goals.

Reviewer 2:

The cost of CF is one of the barriers to adoption in high-volume automotive parts. The reviewer asserted that reducing the material cost by 5% is a required improvement on the cost for CF.

Reviewer 3:

Reduction in energy consumption translates to a reduction in the price of CF. If the processing time can be reduced, this will further reduce the cost. The reviewer indicated that CF cost is a major barrier to wider adoption in vehicles for lightweighting.

Reviewer 4:

The goal is to reduce CF costs; however, the HTC stage is only projected to be a 5% cost reduction in the overall production of CF, which seems very small to the reviewer for the cost and level of the effort.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Comparing the budget to the cost savings, it seemed to the reviewer to be pretty high for the return on investment. The project is building out a significant capability with a speculation of 5% energy savings.

Reviewer 2:

The reviewer said that the team of ORNL and 4XTechnologies combined have the necessary resources.

Reviewer 3:

The remaining funds in FY 2021 and FY 2022 appeared sufficient to the reviewer for the project plans.

Reviewer 4:

It is difficult to tell at this point if the funds are sufficient to carry out this project. The ratio of work done to money spent has not been presented. The reviewer can only assume adequacy of funding because the PIs have not said otherwise.

Presentation Number: mat197
Presentation Title: Multi-Functional Smart Structures for Smart Vehicles
Principal Investigator: Patrick Blanchard (Ford Motor Company)

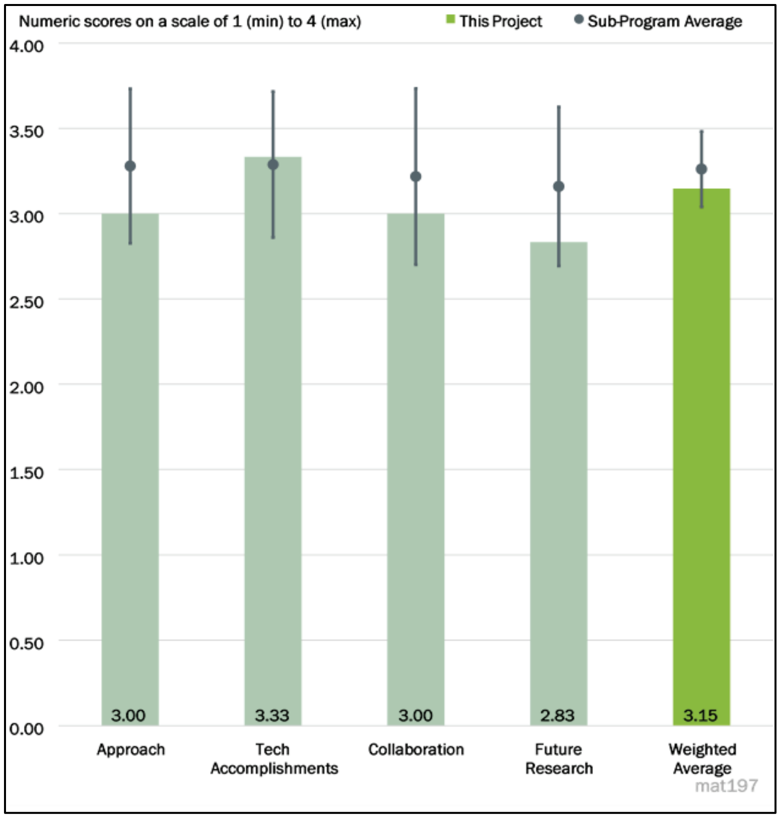

Figure 6-24 - Presentation Number: mat197 Presentation Title: Multi-Functional Smart Structures for Smart Vehicles Principal Investigator: Patrick Blanchard (Ford Motor Company)

Presenter

Patrick Blanchard, Ford Motor Company

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the project is in its early stages but has been well laid out. The research team is focusing on a concept instrument panel, cross car beam with advances in materials, functionality, and process innovations. The task layout structure on Slide 6 and Slide 7 is excellent and provides a clear thought process starting from design through the various process elements.

Reviewer 2:

The composite materials under development could meet the structural requirement and also provide multifunctionality. How to control the distribution and dispersion of the conductive nanofillers in the composites was not very clear to the reviewer, which is an important factor in determining the conductivity of the composites. The high processing temperature of the polymer resin, which makes it hard for electronics component integration, represents one challenge that needs to be overcome.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project is in its early stages; however, all aspects are being addressed in a very comprehensive manner. Specifically, the initial concept of the cross beam is detailed with vision. The reviewer noted that the team has made progress along the lines of early screening of material concepts that have progressed well. Water injection molding and tow placement technologies, sensor integration, joining and attachment, and AM segmented tooling are examples of the progress.

Reviewer 2:

The reviewer said that good progress has been made in terms of component design, water-assist injection-molding testing, composite tape production, the preliminary sensor integration study, evaluation of the manufacturing concept, tooling development, etc.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration and roles across the team were well laid out and clear to the reviewer. The team is comprised of Ford, Michigan State University (MSU), ORNL, Purdue, and Yanfeng Global Automotive Interiors is logical and will strengthen the project plan.

Reviewer 2:

The collaborators seem to work closely with one another. The research is well integrated. The reviewer remarked that the role of MSU is not as clear as that of the other parties.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer indicated that the proposed future research and remaining barriers on Slide 16 and Slide 17 are logical and well thought through. Sensor integrity through the process would be interesting to see in future stages of the work. The dimensional tolerances of the part via water injection molding and tape placement would also be interesting for future designers.

Reviewer 2:

The proposed future research seems reasonable. The reviewer highly recommended that there be more discussions on how to address the pain point (e.g., high processing temperature of polymer resins).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Multifunctional design, integration of sensors, cost reduction in manufacturing, and complex shapes are all leading to lower energy and advancements in automation and EV technologies of the future. The reviewer said that the project has high relevance to DOE objectives.

Reviewer 2:

The reviewer commented that this project, targeting the development of lightweight, multifunctional composite materials, supports the DOE objectives in terms of improving energy efficiency and fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the team has comprehensive resources to address all aspects of this work.

Reviewer 2:

According to the reviewer, the research team has access to all the necessary facilities and resources.

Presentation Number: mat198
Presentation Title: Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure
Principal Investigator: Venkat Aitharaju (General Motors, LLC)

Presenter

Venkat Aitharaju, General Motors, LLC

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

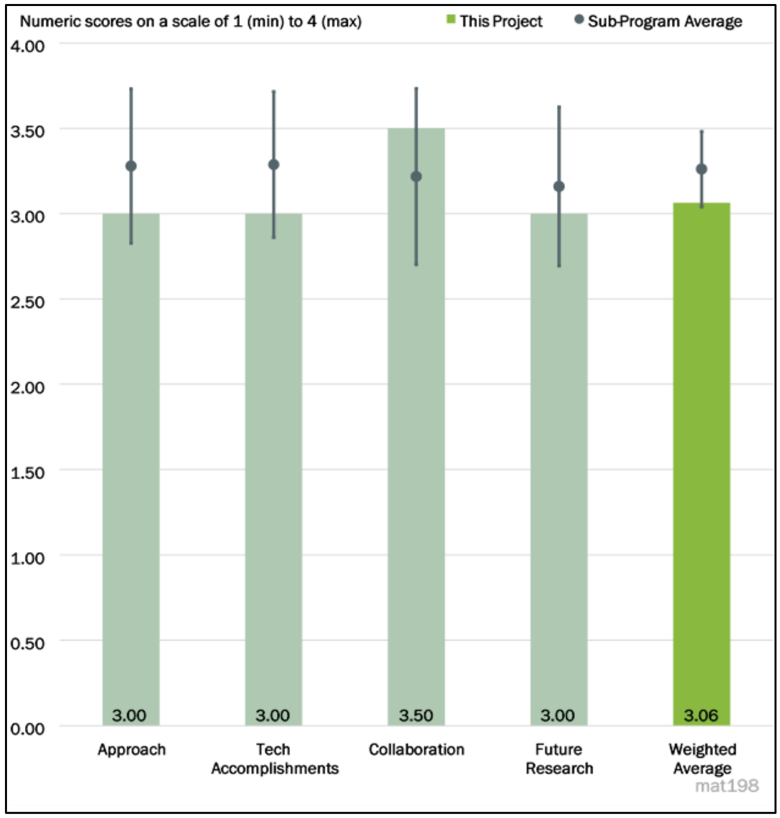

Figure 6-25 - Presentation Number: mat198 Presentation Title: Development of Tailored Fiber Placement, Multi-Functional, High-Performance Composite Material Systems for High Volume Manufacture of Structural Battery Enclosure Principal Investigator: Venkat Aitharaju (General Motors, LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The team has an excellent approach to create multifunctional structural battery enclosures. By investigating different routes to make the enclosure multifunctional (i.e., self-health monitoring, fire-retardant, and electromagnetic compatibility), the reviewer believed the probability of success is high for finding a value proposition for these new enclosures. In the next AMR, the reviewer said that it would be good to clarify if all the added functionalities are planned to be integrated into the same enclosure or if different enclosures are being designed to have different functionalities. Also, because this application is highly dependent on cost, a more robust cost analysis of the composite composition would be useful. For example, it was mentioned that E-glass fiber and PX35 Zoltek CF were selected as the fibers, but a lot of different grades of fiberglass and CF are available at different cost points and with different performance properties. A little more discussion on how the team arrived at those specific fibers would be useful in future AMRs. Overall, it was an excellent approach to the battery enclosure problem that will become more prevalent as EV adoption increases.

Reviewer 2:

The project targets reducing the cost and achieving reduced vehicle weight. Probably due to being a large project, the detailed approach was not communicated. It was not clear to the reviewer how novel these approaches are and why the research team thinks this scope can be a gamechanger for vehicle technologies. Also, it seems these are completely separate tasks, and it was not clear what the synergies of each task are in the project.

Reviewer 3:

The proposed hybrid CF- and GG-based system could provide high-performance multifunctional composite materials. However, the reviewer asserted that the compatibility of these two different types of fibers, particularly for the co-mingling in a tow (e.g., different thermal expansion, weak interfacial interaction, etc.), needs to be addressed.

Reviewer 4:

The approach is broadly interesting from the perspective of hybridizing CF and GF to optimize the cost-to-strength benefit ratio for the target application. However, the approach to that optimization of properties and its execution is lacking in detail and appears to be heavily experimental and somewhat iterative. The reviewer suggested that the project could really benefit from some attempt to rationally model or otherwise approach the optimization in a less Edisonian manner.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Due to the late start of the project, it is hard for the reviewer to compare the progress of this project to other projects that started on time. Despite not having significant technical accomplishments and progress so far, the team did provide a great outline of the plan to accomplish the goals moving forward. With the size of the team on this project, it would be expected that significant progress can be made before the next AMR.

Reviewer 2:

The project started late, but the reviewer indicated that some decent progress has been made in terms of model and experiment design, process evaluation, and instrument setup.

Reviewer 3:

The project is 2% complete; however, initial progress appeared to be encouraging to the reviewer.

Reviewer 4:

The research team has just started the project. Considering the timing, the researchers seem to have made reasonable progress, although it is hard for the reviewer to evaluate because the detailed strategy was not clearly discussed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

With GM having six partners and collaborators as part of the team, the reviewer saw this as a very strong team that was created. There was a great slide outlining the general tasks and expertise of each team member, so overall the coordination across the project team seems very well organized. With the project being only 2 months in, it is hard to determine how well the project team members performed together thus far, but the team and plan established seems well thought out from the start.

Reviewer 2:

The reviewer noted that the team has a broad range of collaborators who appear to bring unique capabilities and resources together for the benefit of the project.

Reviewer 3:

The reviewer said that the collaborators have complementary expertise and the research is well integrated.

Reviewer 4:

The project has a large team, and many institutes are contributing to this project. The project takes advantage of the strength of each team member. The reviewer's one minor comment is that it was not perfectly clear how synergistic all the capabilities are, partly because some of the tasks may not be correlated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

In line with the Approach comments, the reviewer said that it would be beneficial to look at incorporating a rational design and molding approach to the optimization of properties versus relying solely on iterative methods.

Reviewer 2:

With numerous functionalities proposed for the battery enclosure, this enhances the risk mitigation. If one functionality does not perform as desired, then there are other functionalities that can be leveraged to meet the value proposition. However, the reviewer would have liked to have more specifics about the metrics established to determine whether the added functionality is successful. For example, what are the specific values targeted for the self-monitoring electronics, fire-retardant, and electromagnetic compatibility and how do those compare to the properties of current battery enclosures?

Reviewer 3:

The reviewer opined that the proposed future research is fairly general and does not really target any specific issues, which is likely due to the short period that this project has been going on.

Reviewer 4:

The proposed future work is too generic, and it was hard for the reviewer to tell what the actual plans are. Also, the research team did not disclose the detail of the composite battery enclosure. What performance does the team need for the composite battery enclosure and why is the study unique? In terms of the CF and GF study, researchers should calculate what mechanical properties are expected based on the ratio and what the target performance is. Then, the team should be able to estimate the cost benefit versus composite performance. In a sense, what is the acceptable range of properties and cost? Also, the cost estimate and performance estimate should include different kinds of resin choices because that will also impact the expected cost and performance.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project supports DOE objectives of vehicle lightweighting by targeting the weight and functionality of the battery enclosure at a cost of no more than $5 per pound (lb) saved. The use of a hybrid fiber structure will help meet the performance and cost targets set by DOE. If the goals of this project are achieved, then the reviewer asserted that it will provide a significant step forward in meeting DOE's objectives of vehicle lightweighting with the integration of added functionalities.

Reviewer 2:

The reviewer stated that the project could lead to novel lightweight composite materials for vehicle manufacturing with reduced cost. It could also contribute to fuel economy.

Reviewer 3:

According to the reviewer, the project is clearly attempting to address improvements in the cost-benefit ratio of lightweight non-metallic battery enclosures in line with the DOE's identified barriers and needs in the 2017 U.S. DRIVE Roadmap Report, Section 4.

Reviewer 4:

The reviewer said that the project supports DOE objectives toward meeting some of the targets described in the U.S. DRIVE report. However, the proposed direction includes incremental advancement, and the benefit to DOE is relatively limited. The technical advancement may end up being limited to themselves. Considering the large investment by DOE, the reviewer suggested that it would be better that it invests in truly impactful research for vehicle technologies rather than small incremental improvements.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Initially, the budget for this project seemed excessive to the reviewer, but when looking at the size of the project team and all the tasks proposed, the funds are sufficient to deliver on the proposed goals. With the large budget and size of the team, significant accomplishments should be expected in the future years of this project.

Reviewer 2:

The project has an ambitious series of milestones and multiple collaborators. The resources appear—as far as this review can determine—to be sufficient to achieve those goals.

Reviewer 3:

The reviewer indicated that the research team has good resources as well as a significant cost-share commitment to meet milestones in a timely manner.

Reviewer 4:

The research team has access to all the resources needed, according to the reviewer.

Presentation Number: mat199
Presentation Title: Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project)
Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

Presenter

Kevin Simmons, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

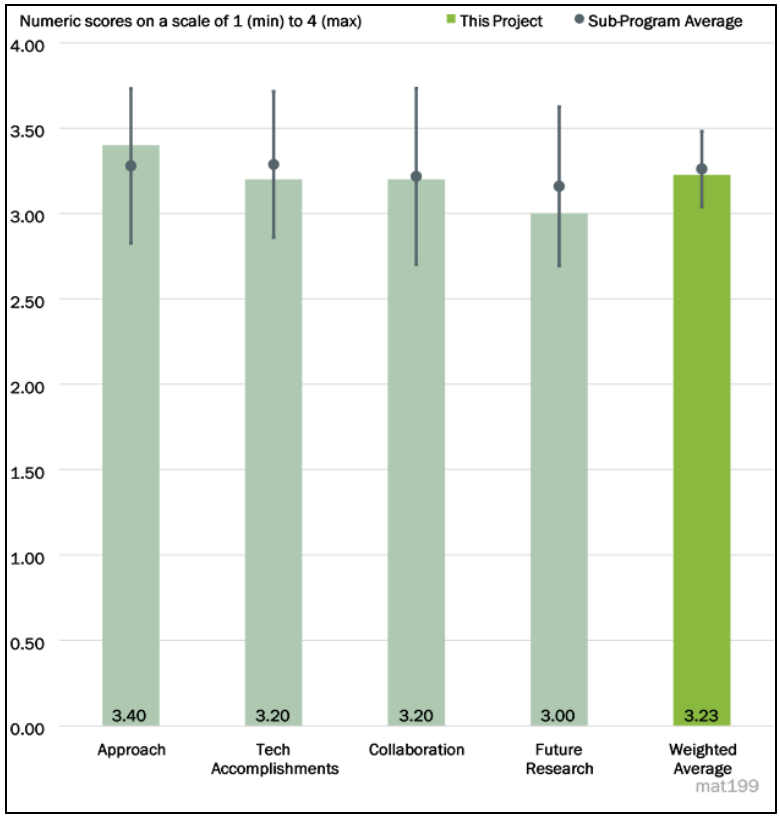

Figure 6-26 - Presentation Number: mat199 Presentation Title: Ultra-Lightweight Thermoplastic Polymer/Polymer Fiber Composites for Vehicles (Inter-Lab Project) Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The target of this project is to develop a high-strength and high-modulus composite material. The researchers proposed polymer fiber and polymer matrix composites with two approaches of development. One is for developing high-strength and high-modulus polymer fibers (strengths greater than 500 megapascals [MPa]), and the other is for developing composite manufacturing processes. The project is split between ORNL (polymer fiber development) and PNNL (manufacturing process development) based on specialties. Overall, the reviewer commented that the project is well designed and the team has shown the feasibility by providing preliminary results.

Reviewer 2:

According to the reviewer, the proposed thermoplastic polymer matrix and polymer fiber composite could provide lightweight materials for manufacturing of vehicles with significantly reduced weight as well as increased recyclability.

Reviewer 3:

The reviewer noted that this is an interesting approach to developing a materials and processing technology that could potentially allow industry to access relatively novel, low-cost, lightweight composite systems.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress made to date indicates that the team is making a coordinated and effective effort to meet the technical goals. The reviewer found that fabrication of both materials and samples are proceeding effectively, and the materials characterization effort is yielding results of interest and relevance. The approach is methodical, and the initial data show promise.

Reviewer 2:

Very good research progress has been made in terms of fiber development, composite fabrication and physical characterization, and mechanical property studies. The reviewer highly recommended more studies on such materials' recyclability.

Reviewer 3:

As a preliminary result from the manufacturing process development side, the team demonstrated polymer panels by film stacking with low void and showed mechanical data from polymer fiber and polymer matrix composites. However, the research team did not show how far (or how close) the current results are from the target performance. The team showed an improved adhesion by plasma treatment. From the fiber development side, the team showed processing temperature (T) range for crystallinity. The reviewer indicated that the progress provided in the presentation is reasonable for 8 months of work.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project is divided into polymer fiber manufacturing (ORNL) and composite process manufacturing (PNNL). The reviewer opined that both ORNL and PNNL teams have expertise in the assigned tasks and the collaboration of the two teams will provide synergetic benefits to the project.

Reviewer 2:

The reviewer noted that the collaborators have complementary expertise (PNNL focused on commercial fiber characterization, surface modification, and processing parameters while ORNL focused on fiber development and characterization, etc.). The research is well integrated.

Reviewer 3:

As far as the reviewer can determine, both laboratories in this collaboration appear to be equally and effectively collaborating for the benefit of the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the proposed path of future research is well defined and logical.

Reviewer 2:

Detailed future research has been proposed with milestones clearly stated. It would have been more helpful to the reviewer if some experiments targeting specific challenges the project is facing now were discussed more.

Reviewer 3:

The reviewer commented that the Proposed Future Research slide does not show specific timelines associated with ORNL's milestones. In the Technical Accomplishments slides, high crystallinity is mentioned to increase mechanical performance of the fibers. However, in the Proposed Future Research slide, a plan about how to achieve high crystallinity is not mentioned. Overall, the Proposed Future Research slide shows some of the milestones without how to achieve them.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the project supports the overall DOE objectives. CF manufacturing is an energy-intensive process, and manufacturing of CF-reinforced thermoplastics is another energy-intensive process. The proposed project is targeting replacing CFs with polymer fibers in composites, which will bring down the overall manufacturing cost and also carbon footprint.

Reviewer 2:

The reviewer said that the stated goals of this project meet DOE requirements for new solutions addressing low-cost, high-volume manufacturing, low-cost fiber reinforcements, and recyclability.

Reviewer 3:

According to the reviewer, the project could lead to thermoplastics-only composite materials that could provide lightweight materials for manufacturing of vehicles with significantly reduced weight. It could also contribute to fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The funding amount is sufficient to develop the technologies.

Reviewer 2:

The cost model for this project would appear to be sufficient to meet the stated milestones to schedule.

Reviewer 3:

The research team has access to all of the resources needed.

Presentation Number: mat200
Presentation Title: Additive Manufacturing for Property Optimization for Automotive Applications
Principal Investigator: Seokpum Kim (Oak Ridge National Laboratory)

Presenter

Seokpum Kim, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

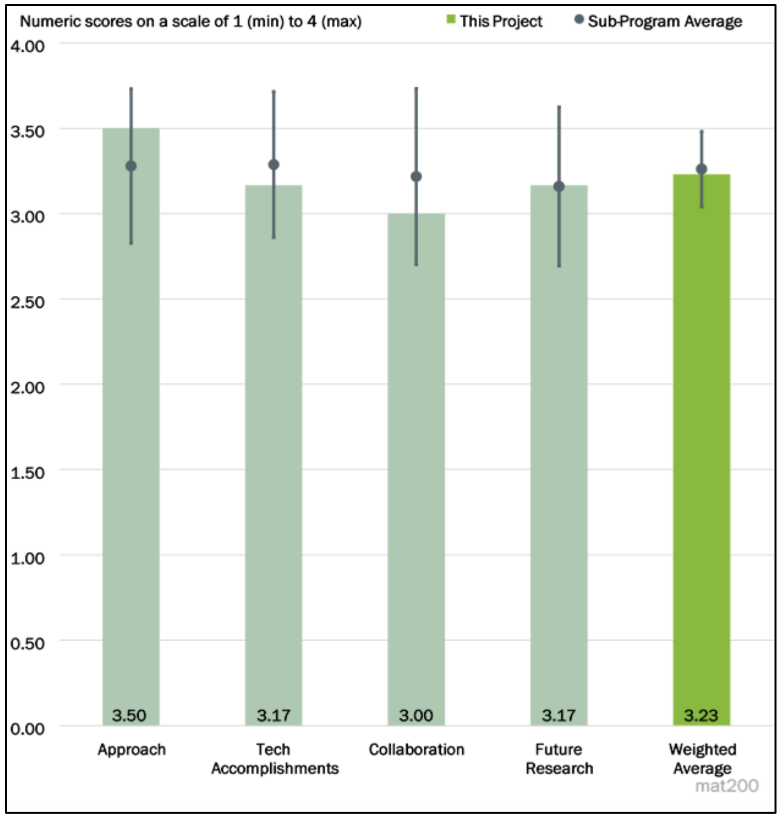

Figure 6-27 - Presentation Number: mat200 Presentation Title: Additive Manufacturing for Property Optimization for Automotive Applications Principal Investigator: Seokpum Kim (Oak Ridge National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project started in October 2020 and has made significant progress. The approach is innovative and feasible. The reviewer found the cellular structure design according to stress distribution to be smart.

Reviewer 2:

The reviewer noted that the project has clearly identified the technical barriers and identified technical targets. The project layout is well organized.

Reviewer 3:

This reviewer stated that the work is a good combination of materials development but is mainly focused on design. The project approach toward the goals is clear to the reviewer, and progress made is commensurate with the project team’s timeline.

The reviewer identified a number of points and questions that can be addressed:

- Because the interest is on lightweighting with a high strength-to-weight ratio, what are the unique testing methods beyond standardized testing that have been employed?

- There are a number of opportunities for materials development. What is the correlation between specific materials development approaches and the team's optimization simultaneous with design?
- What artificial intelligence (AI) methods employed can be specific to lightweighting and will include materials and design development?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Overall, the reviewer commented that the technical accomplishments are matched with the key performance indicators. The demonstrated printable materials and design are what has been proposed. The barriers of the project have been identified. There is a chance to develop new testing protocols that are relevant, including what is unique with multi-axis printing.

Reviewer 2:

The project is on track and has made progress toward the overall objectives. The stress analysis and experimental testing made sense to the reviewer. It would be great if mechanical testing can be in conjunction with DIC. The team may do in situ characterization during printing, if possible.

Reviewer 3:

The presentation was not clear to the reviewer about what accomplishments had been completed. Some of the information presented was from previous years. There are some modeling aspects that the project team indicated were done, but it is not clear what the results were or what the issue was. This was more of a description of what each task was about and not what was accomplished to date.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The ORNL team is teamed up with UCLA. The reviewer found the collaboration to be excellent.

Reviewer 2:

The reviewer suggested that the project team start a more collaborative effort with possible external partners. The armrest demonstration is a good example, although the role and contribution of an external partner can be elaborated more in terms of actual testing and parameters that will see the performance requirements.

Reviewer 3:

It is not very clear to the reviewer which collaborator was responsible for which part of the project. The Collaborations slide, while mentioning the industrial partner and university subcontractor, does not explicitly tell who is doing what task or subtask in the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The direction toward future research was clear to the reviewer and has been stated in the presentation well. It is possible that a new direction toward unique mechanical testing and environmental testing methods can be employed. There is a need for more clarification on the direction of multi-materials printing. Is this based on a gradient approach or is it designed to achieving strength only where it is needed?

Reviewer 2:

According to the reviewer, the future work has been well planned by considering the technical barriers, risk mitigation, and alternative pathways.

Reviewer 3:

It seemed to the reviewer that there has not been much work started. The proposed future work is some of the same work that should have been completed or in progress and demonstrated during this presentation. The project has been in progress for 6 months without much to show about it. The order of the proposed tasks and the work to be completed is logical.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the project is relevant to the mission of the DOE Energy Efficiency and Renewable Energy (EERE) VTO office. It also addresses the challenges of the specific Technology Readiness Level (TRL) level that is mentioned in the phased project timeline. It is important now to define the pathway toward higher TRL levels and identify key collaborations.

Reviewer 2:

According to the reviewer, the project directly supports the overall DOE objectives. The lightweight AM cellular structures are critical for EVs and lowering carbon emissions.

Reviewer 3:

The proposed work could meet the DOE weight reduction objectives. It was not clear to the reviewer whether it meets the industrial collaborators cost and production rates for implementation.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

ORNL and UCLA have sufficient resources and expertise for the project. The project is on track toward the stated milestones in a timely manner. The reviewer indicated that industry involvement helps a lot.

Reviewer 2:

The reviewer affirmed that, yes, the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been clearly identified.

Reviewer 3:

The milestones are timely with sufficient resources; however, it looked to the reviewer like the project is behind, based on no milestone progress for the review.

Presentation Number: mat201
Presentation Title: Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage
Principal Investigator: James Lewicki (Lawrence Livermore National Laboratory)

Presenter

James Lewicki, Lawrence Livermore National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

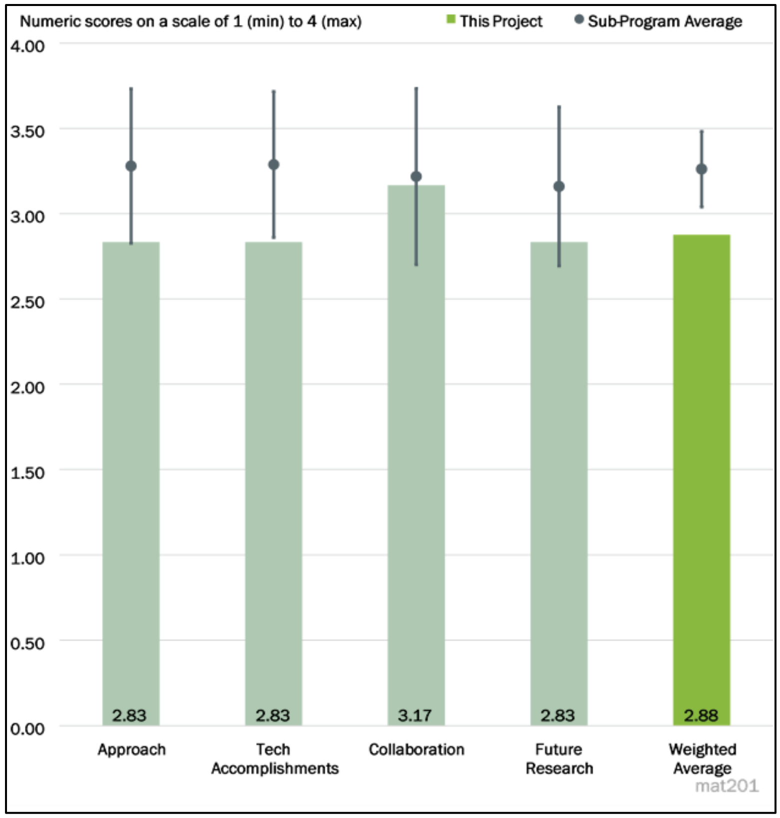

Figure 6-28 - Presentation Number: mat201 Presentation Title: Additively Manufactured, Lightweight, Low-Cost Composite Vessels for Compressed Natural Gas Fuel Storage Principal Investigator: James Lewicki (Lawrence Livermore National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach to the work is clearly defined. However, how the measured improvements in resin properties relate to overall compressed natural gas (CNG) tank performance was not fully addressed, according to the reviewer. Based on the presentation, there should be more effort directed at understanding system-level benefits of using these additives. The team should also include an assessment of the hurdles to high-volume manufacturing, should this approach be proven effective.

Reviewer 2:

Using direct ink writing (DIW) to print multiscale nano-micro reinforced composites for CNG tanks is innovative and of great interest to the reviewer. The new resin with graphene oxide and carbon nanotubes (CNTs) has shown promising results. The team presents a thoughtful pathway (nano reinforcements, short fibers, and long fibers) to overcoming the barriers.

Reviewer 3:

The project is focused on enhancing matrix properties and using AM to reduce compressed gas storage (CGS) costs. The project does not address the primary cost driver, which is high-strength CF. According to the reviewer, the project premise is not sound and would most likely—and in the best of circumstances—result in increased tank costs for CNG applications. The CGS tank industry is highly developed and efficient with filament winding of five tanks at a time. The AM extrusion process is prone to have many defects and has a much slower manufacturing rate. However, the approach toward enhancing the matrix may have some merit for cryo-hydrogen storage to reduce micro-cracks and enhance toughness.

The reviewer strongly urged the team to interact with a CGS tank manufacturer that understands tank certification requirements, SOA materials, and manufacturing methods. The work may result in improved matrices for more extreme environments. The team should be aware that nano-enhanced matrix resins have been developed for tanks in the past 10 years and are kept proprietary. Another chief concern is that tank volume and weight are critical design issues. The current approach using low-performance, chopped CF will seriously reduce tank volume and increase tank weight.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The research team presented clear evidence that improvements in resin performance are possible with the incorporation of nanofillers. This aligns with the July 2021 milestone for this project. Furthermore, the reviewer stated that scalable methods are being investigated for incorporation of high aspect ratio nanofillers into the resin.

Reviewer 2:

The project is on track and has demonstrated progress toward the overall objectives. The preliminary mechanical testing results are encouraging. It would be better if the team could do theoretical calculations (using the rule of mixture) to predict the mechanical performance of the composites. Another one is characterization of the defects in DIW composites during printing. The reviewer asserted that a table is needed to show the costs of graphene oxide and CNTs with reference to conventional CF tanks.

Reviewer 3:

The team was able to compound several formulations and print test coupons. According to the reviewer, the technology may ultimately have value for AM but is very unlikely to be used in CGS tanks.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The collaboration has been excellent. Lawrence Livermore National Laboratory (LLNL) is teamed up with MSC Materials Sciences, LLC, to scale up the composite design and process. The X-ray Computed Tomography XCT Facility at the University of Texas and mechanical testing at the University of Illinois at Urbana-Champaign (UIUC) are essential and helpful, according to the reviewer.

Reviewer 2:

The reviewer indicated that the roles and responsibilities for the project partners are clearly defined with good communication across the team.

Reviewer 3:

Collaborator roles are defined. The reviewer suggested consulting with an actual tank manufacturer to determine if the technology has value. The reviewer also suggested evaluating the DOE Hydrogen and Fuel Cell Technologies Office CGS tank cost model.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The future research is well planned with appropriate decision points and risk mitigation plans. The reviewer opined that it will be necessary for the project to down-select a nano-reinforcement recipe and optimize the DIW process to get fewer defects at low cost.

Reviewer 2:

The proposed work plan addresses most of the key technical hurdles. However, further attention should be placed on the system-level performance of this hybridized design. In addition, the reviewer said that the potential negative effects of tank charging and discharging and resultant fatigue life need to be determined.

Reviewer 3:

The primary focus is on improving strength and stiffness of the AM printing resin. The current performance is far below current practice and not expected to meet requirements. The reviewer suggested that the team seeks guidance from a tank manufacturer to see where the technology could have value.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the work being performed supports the DOE goals for improved energy efficiency through the use of lower cost CNG energy storage.

Reviewer 2:

The project directly supports the overall DOE objectives. The reviewer commented that lightweight, low-cost CNG composites are critical for lightweighting vehicles and lowering carbon emissions.

Reviewer 3:

The reviewer stated that the technology premise is flawed as described above but may have some value in cryo-hydrogen storage.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

LLNL, MSC Materials Sciences, the University of Texas XCT Facility, and UIUC have sufficient resources and expertise toward the stated milestones. The reviewer found that the project is on track and is progressing in a timely manner.

Reviewer 2:

According to the reviewer, the milestones to develop a formulation and print with it are on track.

Reviewer 3:

Based upon the stated progress against objectives, the reviewer indicated that the project remains on track to meet the stated milestones.

Presentation Number: mat202
Presentation Title: 3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles
Principal Investigator: Rigoberto Advincula (Oak Ridge National Laboratory)

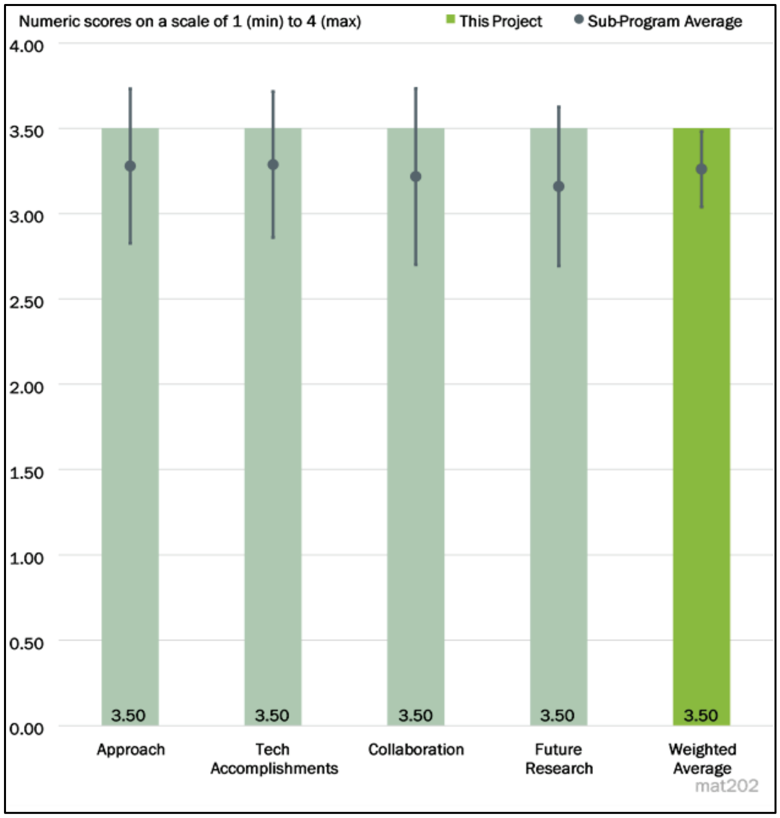

Figure 6-29 - Presentation Number: mat202 Presentation Title: 3D Printed Hybrid Composite Materials with Sensing Capability for Advanced Vehicles Principal Investigator: Rigoberto Advincula (Oak Ridge National Laboratory)

Presenter

Rigoberto Advincula, Oak Ridge National Laboratory

Reviewer Sample Size

A total of one reviewer evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This reviewer observed an excellent breakdown of key tasks and a logical approach to the technical work plan.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer noted a very nice overview of the key accomplishment by project partners.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer described collaboration with project partners as fully clear and in line with project team accomplishments.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

This reviewer asserted that future proposed research supports key project learning.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that the project supports the DOE objectives in supporting and overcoming key manufacturing barriers.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

This reviewer commented that resources were sufficiently deployed.

Presentation Number: mat203
Presentation Title: Low-Cost, High-Throughput Carbon Fiber with Large Diameter
Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

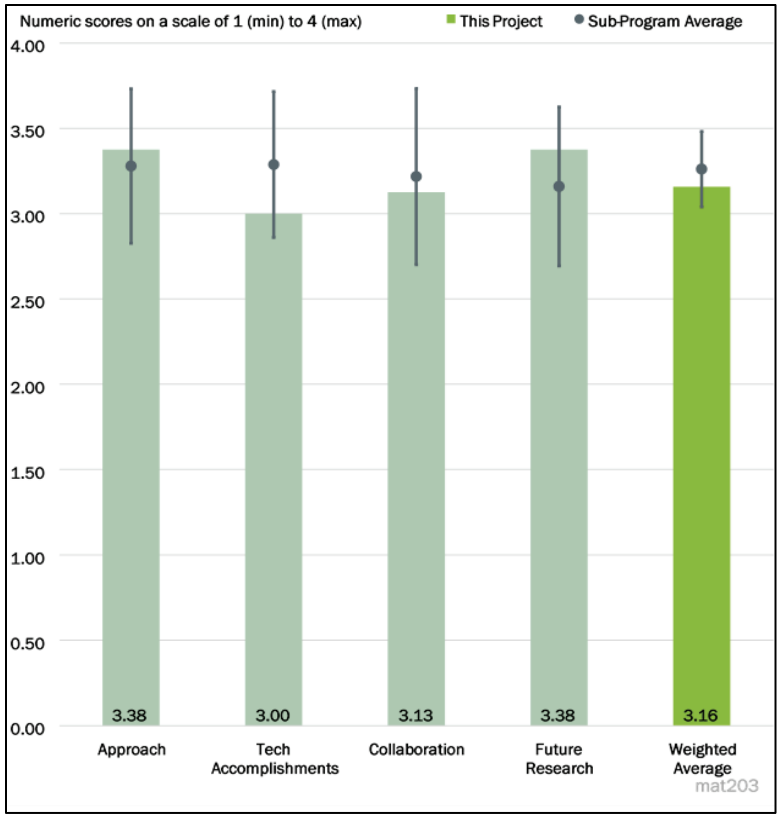

Figure 6-30 - Presentation Number: mat203 Presentation Title: Low-Cost, High-Throughput Carbon Fiber with Large Diameter Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

Presenter

Felix Paulauskas, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is innovative. Large-diameter PAN CFs are very challenging. Using low-cost textile PAN is of great interest to lowering the CF cost. Drying, spinning, and plasma oxidation are promising. The reviewer opined that the PI's work with 4XTechnologies helps the technology transfer.

Reviewer 2:

The project intends to meet DOE goals for CF cost and performance using melt-spun PAN with larger effective diameters. The project plan covers key requirements for fiber production. According to the reviewer, potential issues for composite performance should be addressed as well, including fiber shape effect on packing density and mechanical properties. Dog-bone shaped CF and other shapes were explored in 1970s. The key difference was an aerospace focus on tensile strength versus a DOE focus on modulus.

The reviewer said that the key issue is oxygen stabilization for larger diameter fibers. In fact, the minor diameter of the fiber is actually less than conventional fiber diameters, so diffusion rate should not be an issue.

Reviewer 3:

The reviewer commented that the team has the necessary expertise to process large-diameter textile PAN fibers. The project team is fully aware that the oxidation will be challenging, and it plans to use plasma oxidation to accelerate the oxidation step. How large the textile PAN fiber diameter and cost savings can be for the precursor fibers was not perfectly clear to this reviewer. If the cost savings of the precursor fiber are not significant or people can produce dry-spun textile PAN with much smaller diameters, tackling to process large-diameter PAN fibers for CF production may not have a large benefit. The reviewer suggested considering clarifying the diameter and cost benefit of dry-spun textile PAN fibers and why dry-spun textile PAN fibers cannot be produced in smaller diameters. Is there a technical limitation or a cost reason?

Reviewer 4:

There is interest in low-cost CF as the demand for composites increases. This work is a good combination of materials development but also improvements in the process design. The approach taken by the project team toward the goals were clear to the reviewer and the progress made is commensurate with the timeline.

The reviewer had a number of points and questions to be addressed:

- There is interest in low costs with high strength ratios. What are the unique parameters for evaluating this goal as compared to other fiber fabrication methods? Is it availability, transportation of raw materials, and/or cost of the machine?
- There are a number of opportunities for materials development. What is the correlation between specific materials development approaches and their optimization in an actual composite design? Is there a need to develop a new thermoset chemistry with these fibers?
- What AI methods may be employed that can be specific to improved fiber materials and process design development?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project started on October1, 2020, and is on track. The initial precursor for fiber targeted at 25% larger in effective diameter was delivered. The alternative treatment is also ready for treatment. It was not clear to the reviewer if dog-bone-shaped precursor fibers can be converted to circular CFs.

Reviewer 2:

Overall, the reviewer found that the technical accomplishments are matched with the key performance indicators. The demonstrated low-cost fiber materials and process design proposed are on target. The barriers of the project have been identified.

There is a chance to develop new environmental testing protocols that are relevant for this class of fibers (chopped or winding filament). The reviewer wanted to know whether it is relevant to develop this independent of the thermoset matrix used.

Reviewer 3:

The reviewer said that the project technical goals are well defined. The project is really just getting started. Work thus far is updating the facility.

Reviewer 4:

The delay of the project is understandable due to the COVID-19 situation. However, the project progress is significantly behind schedule. The projected milestone completion is crunched into the last 4 months of FY 2021. The reviewer was not sure if that is a realistic schedule.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, the collaboration has been excellent. The project has teamed up with 4XTechnologies, providing fast technology transfer to industry.

Reviewer 2:

The capability of 4XTechnologies is highly complementary. Textile PAN precursor will be provided by Dralon GmbH. This may be due to the limitation of manufacturers, but the reviewer noted that Dralon GmbH is not based in the United States, and it may be more beneficial to get textile PAN precursor from a U.S. company.

Reviewer 3:

The reviewer commented that the project team is comprised of the critical elements, including PAN fiber production, ozone stabilization, CF conversion, performance, and cost evaluation.

Reviewer 4:

The reviewer indicated that more details on collaborative effort with possible external partners can be stated.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The future research is well planned and on track. The decision points and risk mitigating plans made sense to the reviewer. Alternative treatments have been considered.

Reviewer 2:

Future work is well defined with respect to CF production. The reviewer suggested that the research team should also consider composite manufacturing and performance. Fiber packing is likely to be complex.

Reviewer 3:

The direction of future research was clear to the reviewer and has been well stated in the presentation. Is it possible that a new direction toward more environmental testing can be employed, including exposure of fiber to more extreme conditions?

Reviewer 4:

The mechanical strength targets and cost-analysis plan are well mapped out, according to the reviewer. The project targets processing 25% larger effective diameter fiber in Year 1 and 50% larger diameter fiber in Year 2. Because the baseline diameter is not described, a 25% or 50% larger diameter is hard to evaluate. If the baseline diameter is already large, processing a 50% larger diameter and delivering high mechanical strength within reasonable processing time and energy use will be very challenging. While the general target is good, lack of a detailed strategy, other than process optimization, makes the plan relatively vague.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, the project is relevant to the mission of DOE EERE VTO. It also addresses the challenges of the specific TRL level that is mentioned in the phased project timeline.

Reviewer 2:

According to the reviewer, the project supports the overall DOE objectives, which are developing low-cost, high-strength CFs for lightweight vehicles. This is also critical for EVs and reducing carbon emissions.

Reviewer 3:

The reviewer affirmed that, yes, the project clearly addresses targets for DOE performance and cost.

Reviewer 4:

It is important to establish the process technology for CF production from low-cost precursors. The success of this project may translate to the other low-cost, large-diameter precursors. The reviewer suggested that it will be good to have an estimate of techno-economic analysis in the early stage. If processing dry-spun, large-diameter fiber does not provide significant cost benefit with increasing process costs, it may be rather good to look into investigating dry-spinning textile-grade PAN to reasonably small diameters by manipulating the spinning process and draw ratio.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer affirmed that, yes, the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly.

Reviewer 2:

The project team (ORNL and 4XTechnologies) has sufficient resources for the project to achieve the proposed milestones. The reviewer found that the project is on track and expected to meet the milestones in Year 2.

Reviewer 3:

According to the reviewer, the resources are sufficient to conduct the proposed project.

Reviewer 4:

Resources are sufficient to conduct the research. The reviewer remarked that there is no guarantee that the resulting fiber will meet performance targets—at least no past data were presented.

Presentation Number: mat204
Presentation Title: New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry
Principal Investigator: Tomonori Saito (Oak Ridge National Laboratory)

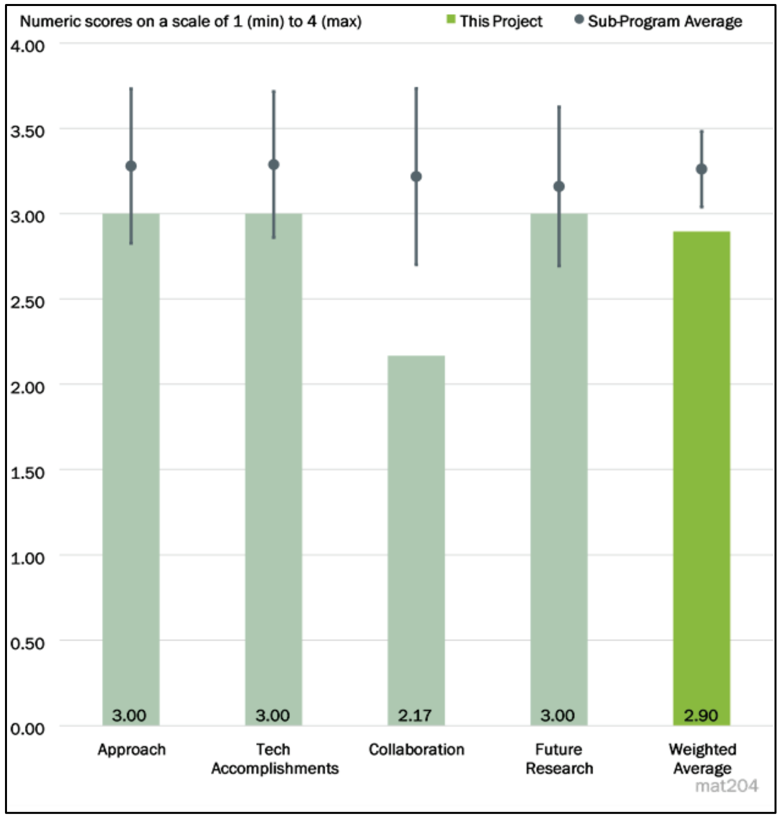

Figure 6-31 - Presentation Number: mat204 Presentation Title: New Frontier in Polymer Matrix Composites via Tailored Vitrimer Chemistry Principal Investigator: Tomonori Saito (Oak Ridge National Laboratory)

Presenter

Tomonori Saito, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has demonstrated the ability to produce vitrimers with properties of interest for advanced composites. Extensive characterization will be required for any safety critical applications, but for now this looked like an interesting technology to the reviewer.

Reviewer 2:

Given the unique reversible bonding nature of vitrimer, the proposed vitrimer-based carbon fiber reinforced composites (CFRCs) could realize the desired welding, repairing, and recycling features. Although the presentation did not show any chemical structures, the project seemed well designed to the reviewer, and the proposed experiments and tests seem feasible.

Reviewer 3:

The reviewer noted that the technical barriers targeted in this project are the lack of low-cost, high-volume manufacturing, joining and repair, and recycling options for current CFRPs. Vitrimer resins have the potential to overcome these barriers through reduced cycle time in production and the ability of them to be reformed and recovered. The targeted production of vitrimer from "commodity polymers" may enable competitive material costs and supply availability relative to vitrimer resins from novel, boutique polymers.

Development of novel modification strategies for CF is less directly applicable to the targeted goals. Dynamic chemistry between the resin and the fiber may enable recycling options, but the reviewer asserted that recovery of CFs from the CF and vitrimer system to demonstrate this advantage is not identified in the milestones or the future work. Custom fiber sizing increases interfacial bonding and composite performance but does not lower cost for high-volume manufacturing or enable joining or repair.

Part of the second-year scope of the project (the September 30, 2022, milestone) and the first-year accomplishments reported is demonstration of CFRP manufacturing by prepregs and stamping with conventional resins. While baselining the vitrimer resins is important, CFRP production using prepregs and stamping should be known technology by ORNL. Its demonstrations are not a meaningful milestone of this vitrimer resin project, according to the reviewer.

The feasibility of the vitrimer systems explored for overcoming the technical targets was difficult for the reviewer to assess as no information is provided regarding the chemical systems and approaches pursued.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Pretty good research progress has been made, including vitrimer synthesis, mechanical property studies, CF surface functionalization, as well as CFRC preparation. It seemed to the reviewer that the processing temperature of current vitrimers is a little bit low, but further optimization is definitely feasible.

Reviewer 2:

The reviewer said that two resins were developed, with strong progress toward meeting Year 1 milestones.

Reviewer 3:

According to the reviewer, no information is provided on chemical systems and approaches being pursued (only vitrimer resin 1, crosslinker-a, etc.). No information is provided on the nature of CF functionalization (only X-ray photoelectron spectroscopy [XPS] confirmed). Tensile strength targets appear to be successfully met for both resin 1 and resin 2.

Milestone progress appears to be on track, but other than the 25 MPa strength performance, most of the milestones involve accomplishments like designing, quantifying, and identifying with numerical targets and were therefore difficult for the reviewer to use to measure progress toward project goals.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

ORNL states collaborators will be selected at a later date to include fiber, resin, and OEMs. The reviewer said that this is a sound strategy.

Reviewer 2:

It seemed to the reviewer that there are no official collaborators or partners at the current stage, although the PI has reached out to some potential partners, and some of them might join the collaboration at a later stage toward commercialization.

Reviewer 3:

The reviewer reported that the project only has one participant, ORNL, and does not involve collaboration or coordination with other team members. However, collaboration partners are proposed to be pursued "As the project progresses, toward commercialization," but the reviewer indicated that the project would benefit from an early stage by communication with resin suppliers, compounders, molders, and OEMs to identify performance targets and commercial feasibility of approaches pursued.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Future proposed research is appropriate. The reviewer suggested including existing commercial-sized CF as part of the evaluation to be less disruptive to the supply chain.

Reviewer 2:

The proposed research seems to align with the project aims very well. There are a lot of parameters the PI can play with. The reviewer suggested that a recyclability study should be one of the key research tasks.

Reviewer 3:

The reviewer indicated that decisions point at the end of the first year and the end of the second year involves resin mechanical performance (35 MPa tensile strength) and CF composite performance (500 MPa tensile strength). Verifying resin and composite mechanical performance is a reasonable strategy to compare the novel resin systems to current SOA automotive resins. The reviewer asserted that the inability to meet strength performance would be a significant barrier to realization of the proposed technology.

The target vitrimer resins are proposed, however, to address the CFRP barriers of high-cost, low-volume manufacturing, inability to join or repair, and the inability to recycle. None of these potential advantages of vitrimers that justify investment in vitrimer development is addressed by the project decision points or by the milestones and deliverables (at least the ones provided here that cover Year 1 and Year 2 of the project). These points are mentioned in the Remaining Challenges and Barriers, but details on strategies to measure progress toward them or address them are not described in the Proposed Future Research other than “optimizing the resin chemistry, fiber functionalization, and composite fabrication process.” Without details it was difficult for the reviewer to assess mitigation of risk through consideration of multiple development pathways. The development of vitrimer resin 1 and vitrimer resin 2, with two orders of magnitude difference in strain-to-break, may represent two distinct technology alternatives to mitigate risk if one is found not to be suitable.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, the stated goals of the project— to decrease processing time, increase repairability, increase recyclability, and increase affordability— directly support overall DOE objectives.

Reviewer 2:

The reviewer commented that the proposed vitrimer-based composites could provide affordable CFRPs with re-processability, recyclability, and repairability, aligning well with the VTO goals for lightweight vehicles.

Reviewer 3:

The biggest advantage to the vitrimer technology is that it may provide a better pathway toward recycling while maintaining more of the virgin composite performance. The vitrimer technology should provide the best characteristics of thermosets and thermoplastics. The reviewer asserted that cost is critical and has not been discussed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Resources are sufficient to meet the project milestones. The reviewer stated that movement toward commercialization may be lengthy and extensive, depending on the vitrimer synthesis process and cost.

Reviewer 2:

The reviewer stated that the PI has access to all the necessary facilities and resources.

Reviewer 3:

According to the reviewer, the stated milestones are not ambitious but are vague and listed mostly as actions rather than measurable achievements. They will be easily met with remaining resources.

Presentation Number: mat205
Presentation Title: Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites
Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

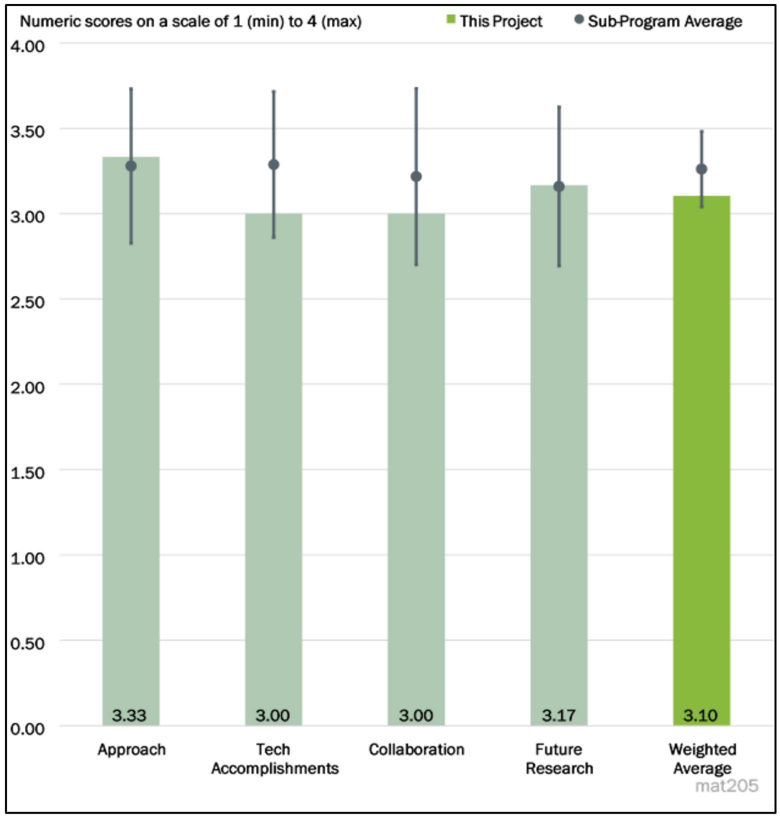

Figure 6-32 - Presentation Number: mat205 Presentation Title: Adopting Heavy-Tow Carbon Fiber for Repairable, Stamp-Formed Composites Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

Presenter

Amit Naskar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

67% of reviewers felt that the project was relevant to current DOE objectives, 33% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that pros of the technical approach include use of commodity fibers instead of nanofibers and nanomaterials, and activating fiber surface for enhanced adhesion. The reviewer that it was unclear why polypropylene (PP) was chosen; polyethylene (PE) is the commodity polymer with larger market volume and lower resin pricing.

Reviewer 2:

Developing an optimum sizing chemistry for CF to use with thermoplastic resins is a challenging problem, and this reviewer indicated that it is nice to see the project address this hot topic. The reviewer suggested that sizing chemistry needs to be optimized from various performance requirements—strength, molding process, and loading type such as impact, fatigue, etc. The project is well designed and take into consideration the previously mentioned requirements. Additionally, the objectives set for the mechanical performance makes sense—strength between 0.8-1.4 Gpa, 50-100 Gpa for stiffness, etc.—with large tow continuous CF composites.

The reviewer remarked that it is not clear what the plans are in meeting the cost reduction object (30-50%?). Furthermore, the objective of meeting a 100 MPa tensile strength using discontinuous fiber materials is very low for a volume fraction around 30%. The reviewer explained that commercial thermoplastic materials already provide a strength around 200 MPa using discontinuous CF materials (1 in long) with 30% volume fraction. Can the project team elaborate on the metric?

Reviewer 3:

Given the number of DOE CF composite programs funded, this reviewer suggested that the project team develop a more specific list of barriers that would be relevant to the project. The barriers listed are too broad and there is not a clear link between project deliverables and listed barriers. The reviewer stated that notably more is understood regarding CF systems since the publication of February 2013 light-duty technical requirements.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Milestones were met on time or ahead of time, which this reviewer described as commendable. The reviewer further reported that the first stage of the manufacturing approach was determined.

Reviewer 2:

The reviewer observed reasonable technical progress as the project plan was developed. However, the plan does not adequately describe the direct link to barriers.

Reviewer 3:

This reviewer pointed out that one of the AMR presentation figures showed that treated CF composite yields a strength of 138 MPa at a volume fraction close to 22%. Is this with the continuous or discontinuous fibers? What are the volume fractions?

Additionally, the reviewer noted that the unidirectional PP composite with CF showing improvement in the composite ductility was shown. What is the mechanism involved in achieving a ductility greater than 20%? The reviewer also asked why the stress versus strain curve is showing a change in slope at around 8% strain, and what phenomenon is involved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Good collaboration was established with a university, and the reviewer commented that it was great to see the project support a graduate student and aid in workforce development.

Reviewer 2:

The reviewer remarked that the level of progress is in line with the required collaboration and coordination.

Reviewer 3:

This reviewer indicated that it was good to see greater collaboration between the researchers inside ORNL. However, it was not clear what kind of collaboration exists between ORNL and the University of Tennessee, and the reviewer requested a description.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer noted that detailed plans were provided for future work, and project success measures were established early in the form of milestones and go/no-go points.

Reviewer 2:

This reviewer observed very detailed and specific future work, with no clear indication of overcoming the barriers listed.

Reviewer 3:

The reviewer described proposed future work as well laid out and reported that the project goal is to work with large-tow fiber systems. It was not clear why work over the last year involved commercial, small-tow fiber systems.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project directly supports DOE objectives in developing cost-effective high-performance thermoplastic composite material systems for the U.S. industry.

Reviewer 2:

Developing lightweight automotive materials at low cost using commodity precursors was described by this reviewer as essential for reducing automotive weight and enhancing fuel efficiency while decreasing GHGs.

Reviewer 3:

Unfortunately, this reviewer did not understand how this project would help achieve DOE objectives. The barriers listed are too broad and not relevant to what has been understood about CF composite systems in vehicle body structures. Perhaps, it was the way the project was presented and reviewed, or this reviewer's lack of understanding regarding the key project objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

This reviewer noted sufficient resource utilization.

Reviewer 2:

The reviewer asserted that the resources proposed to meet project deliverables are sufficient.

Reviewer 3:

Future plans seemed to align with the level of funding provided from this reviewer's perspective.

Presentation Number: mat206
Presentation Title: Soft Smart Tools Using Additive Manufacturing
Principal Investigator: Jay Gaillard (Savannah River National Laboratory)

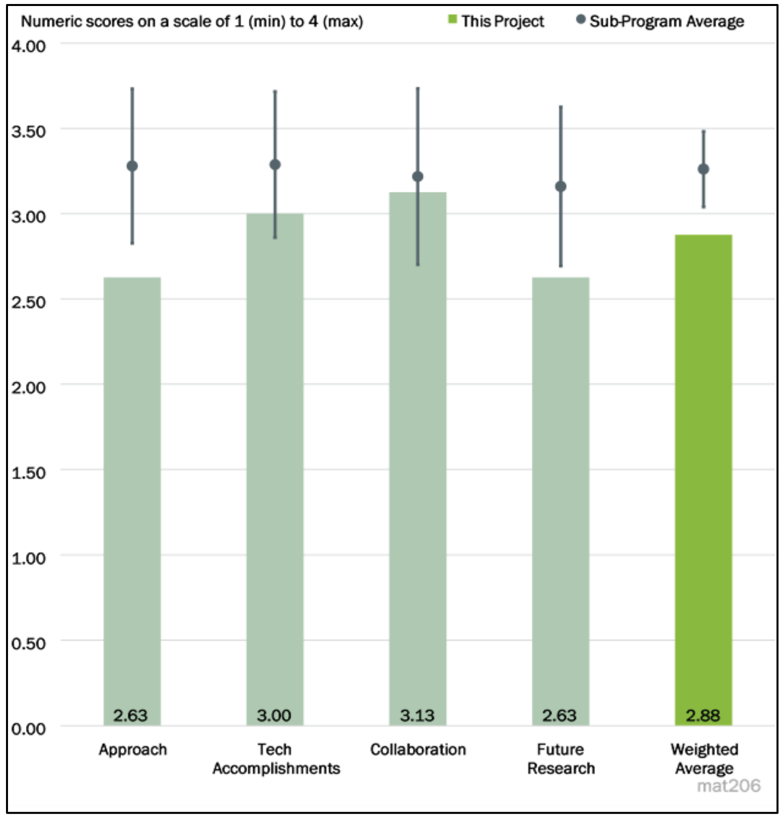

Figure 6-33 - Presentation Number: mat206 Presentation Title: Soft Smart Tools Using Additive Manufacturing Principal Investigator: Jay Gaillard (Savannah River National Laboratory)

Presenter

Jay Gaillard, Savannah River National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer liked the approach of using 3-D printing for tooling as opposed to using 3-D printing to directly fabricate parts. With the automotive industry needing high-volume parts, 3-D printing the tooling is a much more viable route to utilize 3-D printing in industry. The objectives are clearly laid out and the approach is excellent in targeting increased strength and increased thermal conductivity and integrating sensors into the 3-D printed tooling part. One aspect that could be added is quantifying the durability of these tooling parts compared to current industrial tooling parts. The use of electromagnetic (EM)-coupled heating compared to conventional heating is a great route to explore and could reveal significant improvements in industrial processing.

Reviewer 2:

The reviewer indicated that, generally, the project is well designed for the proposed tasks. Understanding how microwave heating affects various properties is an especially interesting approach. However, it is a little confusing how microwave heating is connecting to 3D printed sensor. While development of printable sensors itself is an important research subject, is EM-coupled heating critical for a sensing capability? The impact of the project seemed vague to the reviewer. The project aims to reduce tool cost and the curing cycle and lower thermal gradients. Are these parameters actually major issues in vehicle manufacturing?

Reviewer 3:

According to the reviewer, the project does not identify what type tooling or process it intends to support, and thus there are little criteria for success metrics. Polymer AM tooling has been demonstrated over the past decade and this project would appear to do little more than drive up the cost. With that being said, the TRL Level 2 effort could result in some technology like multifunctional structures that could be useful in some applications. America Makes funded a project about 6 or 7 years ago that demonstrated a higher level of embedded sensors and electronics.

Reviewer 4:

The project focus per title and project objective is soft tooling for automotive applications. The reviewer had several questions that were unanswered in the presentation or during the Q&A:

- What are the process and tooling technology that are being investigated?
- What is the target size of the tooling?
- What are the requirements on the tool (loads, temperatures, surface finish, etc.)?
- What is the expected life of the tooling?

Without answering at least some of these questions, investigation of AM with sensors is perhaps a worthwhile exercise but does not have a target or actual application.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Great progress has been made in evaluating the effectiveness of microwave heat treatment of the parts and in evaluating the best materials to be integrated into the parts to improve the microwave heating. The tensile strength results of the microwave-annealed parts are very promising, but the reviewer suggested including error bars in the tensile strength results to show the variability in part performance after the microwave heat treatment. The reviewer thought that the microwave heat treatment could also reduce the tensile strength result standard deviation over the baseline parts, which could serve as another reason to use that annealing process. The team has made great progress in evaluating different 3-D printed materials as well.

Reviewer 2:

Considering that this is the first year and especially during the COVID-19 pandemic, the reviewer stated that the team has made very good progress.

Reviewer 3:

This reviewer reported that the project just started and the researchers are investigating AM techniques with various fillers as well as direct-write techniques with conductive inks. Hyrel equipment is used for both efforts. Without targets, the reviewer asserted that this is exploratory work.

Reviewer 4:

The reviewer opined that the technical goal of using radiofrequency (RF) energy to anneal the tool seems misguided at best because a simple oven works fine. Ideally, the RF would be used to heat the tool during processing, such as curing a resin, but this is not the team’s objective. Printing sensors on the tool might seem like a good idea; however, the tool typically requires machining after the print and any surface sensors would be lost.

The team was able to compound some AM feedstocks, print with them, and show some property improvements. Similar work had been accomplished 10 years ago. Conductive ink was applied to the tool surface to be used as a pressure sensor. Again, this was nothing new. The reviewer suggested that the EM susceptor microwave heating is the most novel accomplishment and should be applied in-process rather than in tool annealing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer commented that the project team consists of an excellent combination of partners that are tackling different tasks within the project, and the collaborator overview slide clearly defines the tasks for which each partner is responsible. One thing that could be clarified in the presentation is that when discussing the results, the collaborator and partner that performed the work could be mentioned on that specific slide. Overall, based on the progress made so far, it seemed to the reviewer that the project team is coordinating research activities very nicely.

Reviewer 2:

The team seems to be making ample use of collaborators; however, the reviewer suggested that having an end-use application for the tool technology would provide more focus and realism. In many cases, polymeric AM tooling has proven more expensive than CNC machine Al tooling and has a shorter service life.

Reviewer 3:

The research team has a synergistic collaboration for this research project. One suggestion is to plan for commercialization of the technology in the future. From looking at the roles, the reviewer commented that none of the institutes in the team will be the one to commercialize the technology.

Reviewer 4:

It appeared to the reviewer that collaboration is planned. Given the fact that this project just started, it would not be fair to judge the quality of collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed work is nicely described in a logical manner and the goals seem achievable in the project's timeframe. The proposed work also mentions more materials to evaluate so that greatly mitigates risks of some materials not performing as expected. One thing that can be considered for future work is discussing how the annealing process could be scaled up. The reviewer noted that some tooling parts can be very large, so discussing how the energy and time to anneal a part could change with the size of part would be valuable.

Reviewer 2:

The research focuses on annealing of parts and on printing with polyetherether ketone (PEEK) and polyetherketoneketone (PEKK) materials and continuous fiber. This is interesting academic work; however, the relation to tooling applications needs to be defined. What are the loads that this tooling needs to withstand? What are the tolerances and surface finish that need to be achieved? This is clearly low TRL level work; therefore, the reviewer asserted that questions about print speed to produce reasonably sized parts and about cost can be delayed. Techno-economic analyses should be performed in future years.

Reviewer 3:

The reviewer strongly suggested that the team evaluate similar technology that has already been developed and demonstrated. The team should consult with a potential end-user, like a resin transfer molding (RTM) fabricator, for example, to gauge merits and practicality of what is being sought. RF tool heating may have merit.

Reviewer 4:

In the proposed research tasks, the team has solid research plans, although it was not perfectly clear to the reviewer how the researchers plan to deliver Milestone 3.4 (25% reduction in energy consumption). In addition, is Milestone 3.3 supposed to be a test plan? If so, Milestone 3.3 is a strange milestone considering that is the final year of the project.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project supports DOE objectives by investigating routes to reduce tool cost, reduce cure cycle times with in-situ monitoring, improve part consistency, and increase tool durability. This would result in reducing overall cost of vehicle production, which meets DOE objectives.

Reviewer 2:

Smart sensing for tools is very important for vehicles and many other applications. The connection of EM heating for smart tooling was not clear to the reviewer, while EM heating is an interesting technique to investigate.

Reviewer 3:

This is a fundamental study of manufacturing and materials problems. The reviewer asserted that relevance to automotive tooling needs to be defined.

Reviewer 4:

It was not clear to the reviewer what DOE objectives are being met with this project. Polymer AM tooling was developed for rapid, low-cost, limited-life part demonstrations. This project would greatly increase tool cost and complexity. There may be some niche application, and the reviewer suggested that the team should consult with part fabricators to find some application pull to solve a problem without a conventional solution. Tool design taking advantage of RF heating is a missed opportunity.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources appear to be sufficient to meet the milestones within the given timeline. The progress thus far shows that the team has used the current funds effectively, so the reviewer believed that the project team will continue to deliver within the budget and timeframe.

Reviewer 2:

Resources for the project are sufficient, according to the reviewer.

Reviewer 3:

The reviewer found the resources to be sufficient.

Reviewer 4:

Resources appear to be sufficient to meet milestones; however, the reviewer said that it would be best to add a tool demonstration that solves a real problem.

Presentation Number: mat207
Presentation Title: Multi-Material, Functional Composites with Hierarchical Structures
Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

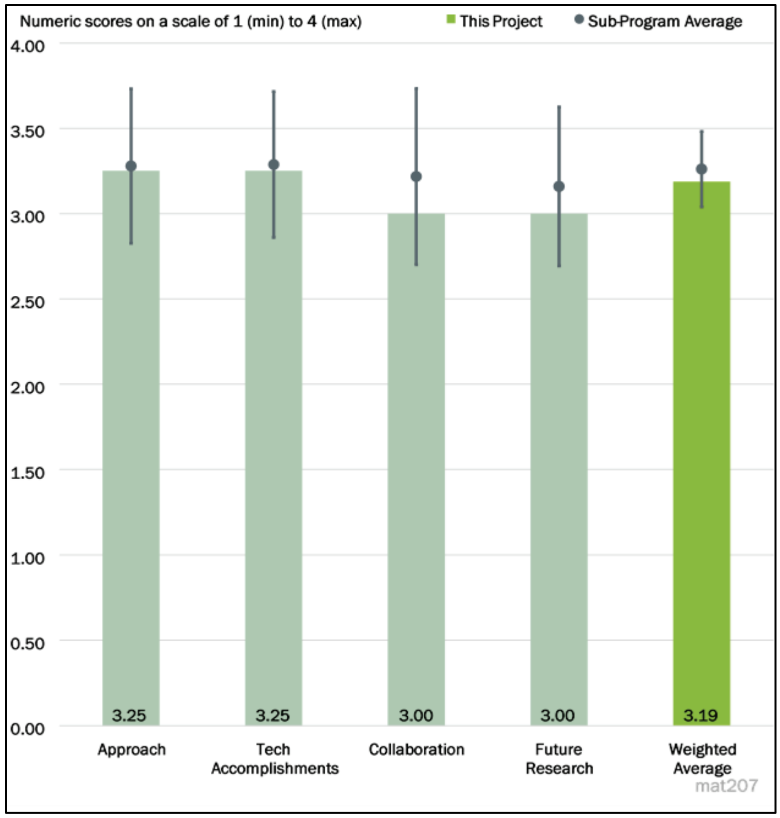

Figure 6-34 - Presentation Number: mat207 Presentation Title: Multi-Material, Functional Composites with Hierarchical Structures Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

Presenter

Christopher Bowland, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach of developing multifunctional composites for self-health monitoring by integrating ferroelectric particles on the surface of the fiber tows is very novel and innovative. The reviewer said that the project is well designed with important task breakdowns, milestones, and go/no-go decision points.

Reviewer 2:

The objective is to impart multifunctional performance into a composite without adding parasitic weight. The objective is met by improving composite shear strength and imparting apparent piezoelectric behavior to measure mechanical strain. A control sample was not discussed, but the reviewer opined that it could be the silver paint that is responding to strain rather than the coating with discrete particles.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The progress on the project so far was promising to the reviewer. It is nice to see the relation between the applied excitation energy and the voltage measured on the composite material system. Additionally, the reviewer was glad to see that the mechanical performance is also improving after integrating the ferroelectric nano particles.

The reviewer suggested that it would be helpful to collect the data on a greater number of samples to determine the variance and also determine the efficiency of the manufacturing process of nanoparticle integration. The main assumption here seems to be that damage in the composite would result in a different amount of voltage for a given excitation. If so, the reviewer commented that this assumption should have been tested first by measuring the voltage with a different percentage amount of $BaTiO_3$ in the composite.

Reviewer 2:

A nano-coating was applied, and the data show marginal improvement compared to the sized fiber. The reviewer stated that discrete particles are unlikely to form a continuous electrical circuit for simple harmonic motion (SHM). A control sample for strain was not discussed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project seemed to the reviewer to have good coordination between ORNL and Columbia University.

Reviewer 2:

The reviewer said that the collaboration effort with Columbia University has yet to begin.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Proposed future work will be sufficient once the baseline is validated against the silver paint. The reviewer suggested also looking at the state sensor at rest after some damage is imparted rather than when the structure is under strain and vibration during car driving. The data acquisition package is likely too expensive for automotive applications.

Reviewer 2:

The reviewer would have liked to see the sensing and energy harvesting data captured on more samples to determine the performance variation. The reviewer did not see any update from Columbia University and would have liked to see some preliminary work conducted at Columbia University in the last year to get them onboard with the entire project. This would keep both ORNL and Columbia University on the same page.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that, yes, this project supports overall DOE objectives in developing novel multifunctional composites to make a strong business case. The development of multifunctional capability explored in this project (self-sensing) is very important and will enable implementation of more lightweighting applications in the industry.

Reviewer 2:

Composite structural integrity was a concern to the reviewer and a barrier toward broad application in the automotive sector, primarily in the area of barely visible damage. The approach could have merits but is still at TRL Level 1-2.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, the resources proposed in the project to achieve the stated milestones are sufficient.

Reviewer 2:

Resources appeared to the reviewer to be adequate for the proposed milestones.

Presentation Number: mat208
Presentation Title: Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste
Principal Investigator: Lelia Cosimbescu (Pacific Northwest National Laboratory)

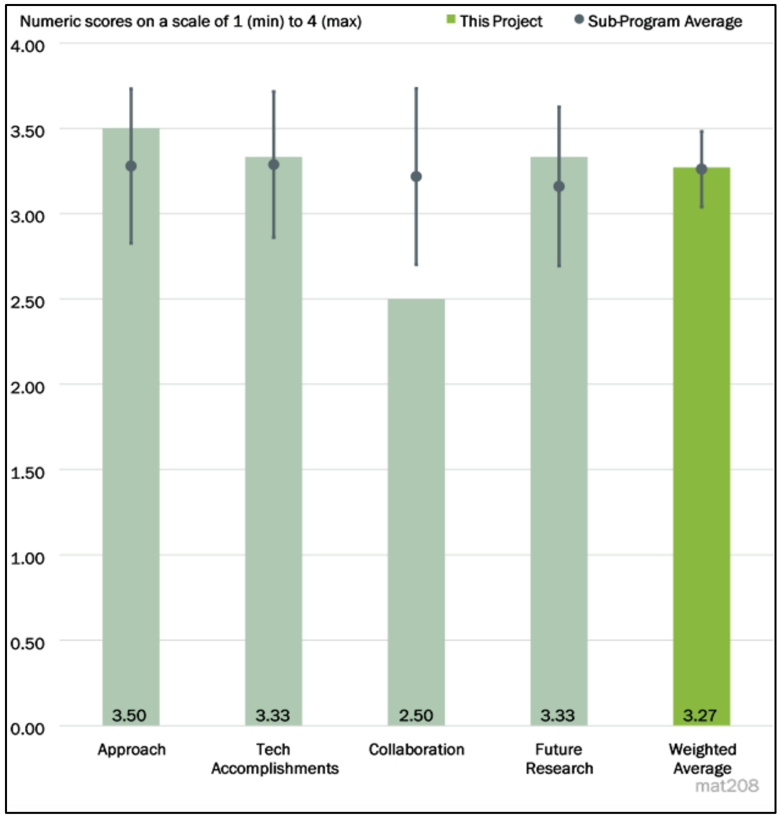

Figure 6-35 - Presentation Number: mat208 Presentation Title: Efficient Synthesis of Kevlar and Other Fibers from Polyethylene Terephthalate (PET) Waste Principal Investigator: Lelia Cosimbescu (Pacific Northwest National Laboratory)

Presenter

Lelia Cosimbescu, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project has an excellent approach to creating aramid fibers from a recycled starting material. This is a unique approach that could result in methods to generate cheaper aramid fibers while also reducing plastic waste and could help aramid fibers see more use in vehicles. The project is designed well in the logical progression of optimizing the synthesis process with the end goal of producing fibers that can be demonstrated in bulk composites. One of the biggest barriers the reviewer saw is producing the fiber. Aramid fiber spinning is not a trivial task, and the project team has identified collaborators and partners to approach to assist with that barrier.

Reviewer 2:

The reviewer commented that the approach is well outlined, and barriers already encountered, such as dissolvability of polyethylene terephthalate (PET) in practical solvents, have been addressed.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The project has met the milestone of demonstrating PET deconstruction with a yield of at least 85%. Overall, the project has made very good progress with the deconstruction of PET from a mixed waste stream. There are some residual PET particles after deconstruction, but the reviewer did not see that as much of an issue as long as the yield of at least 85% is still met. The team has also made good progress with preparing four polymers via the traditional route.

Reviewer 2:

According to the reviewer, the project just started, and the researcher has already identified and addressed some key issues.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

There were no collaborators in the first stages of the project. For the initial stages, the team had the expertise to perform all the deconstruction and polymerization work so collaborators were not needed. Suggestions were made for establishing a collaboration with the University of Tennessee and the University of Washington for fiber production. The reviewer advised the project team to establish a partner for fiber production as soon as possible because fiber spinning can have a big learning curve to produce good fibers with consistent diameters and consistent geometries along the length of the fiber.

Reviewer 2:

The reviewer remarked that this appears to be a small project in its infancy. Possible project partners have been identified.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed future research was planned well. Good risk mitigation was established by proposing different routes to improve the solubility of the polymer in order to determine the molecular weight. In terms of scale-up, the reviewer suggested having plans to be able to produce numerous 20- gram (g) batches of the polymer due to the amount that will be required to perform the fiber spinning. The techno-economic analysis is vital for this project, and the project team has discussed that as a goal in the final year of the project.

Reviewer 2:

The reviewer noted that the PI has identified issues and proposed feasible ways of attaining aramid chemistry. Spinning of fibers needs to be addressed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This project supports DOE objectives. While other projects are investigating ways to reduce the cost of CF, other fibers are needed to replace CF for different composite applications. By reducing the cost barrier for aramid fibers, the reviewer asserted that the team could see more use in vehicle composites that were not previously deemed cost effective and could reduce the vehicle's overall weight.

Reviewer 2:

Upcycling of PET into Kevlar®-like fibers would be a breakthrough, according to the reviewer.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the resources are sufficient to meet the stated milestones. As long as the project team finds a good collaborator with fiber-spinning capabilities, then the project should have sufficient funds.

Reviewer 2:

The initial research can be performed on the current budget; however, if successful, the reviewer stated that the budget and scope should increase. Collaboration with partners with a strong background in spinning fibers and composite research should be established.

Presentation Number: mat209
Presentation Title: Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling
Principal Investigator: Gregg Beckham (National Renewable Energy Laboratory)

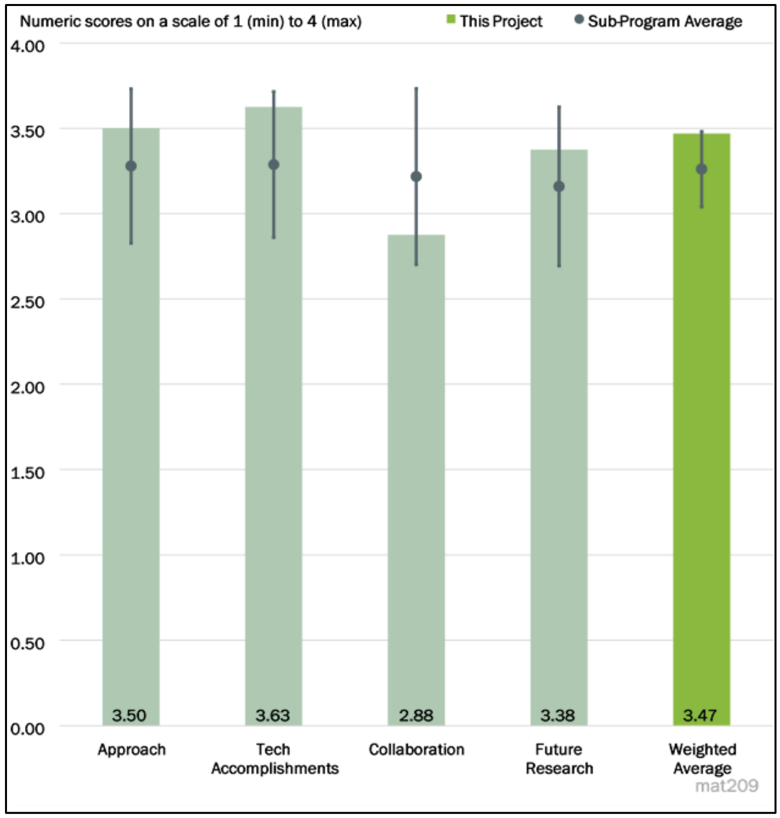

Figure 6-36 - Presentation Number: mat209 Presentation Title: Bio-based, Inherently Recyclable Epoxy Resins to Enable Facile Carbon-Fiber Reinforced Composites Recycling Principal Investigator: Gregg Beckham (National Renewable Energy Laboratory)

Presenter

Gregg Beckham, National Renewable Energy Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this project explicitly addresses two of the five critical challenges for carbon fiber (CF) composite materials—low-cost fibers (achieved here through fiber reuse) and recycling. The investigators demonstrated within the first quarter of the project that bio-based, covalently adaptable network resin system has a similar storage modulus and a glass transition temperature (Tg) as a standard epoxy-amine system and moved on to addressing the focus of the work—carbon fiber reinforced polymer (CFRP) recycling.

Low-temperature and low catalyst demonstrations of recycling were pursued, with acknowledgment of potential trade-offs between facile recycling and mechanical performance. The reviewer appropriately appreciated the need for maintained performance in subsequent generations of recycled material.

The project is well designed to identify multiple chemical paths to target resins, to quickly move to scale-up of candidate resins for processing and property demonstration, and to identify alternative strategies to mitigate risk if the target system does not meet required performance.

The reviewer asserted that the project approach is also strong in leveraging collaboration with other DOE investments (National Wind Technology Center, BOTTLE™ [Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment], and Renewable Carbon Fiber Consortium) and in considering techno- economic analysis (TEA) and Materials Flow through Industry (MFI) models relative to existing materials from the beginning of the project.

Reviewer 2:

The project addresses the problem with recycling CF composites by developing a recyclable epoxy-anhydride covalently adaptable network using bio-derived precursors. The reviewer called this a great approach to creating recyclable CF composites to recover both the matrix and the fibers without degrading the fiber integrity. From the start, the project team is keeping in mind life-cycle analysis (LCA) and TEA for this approach, which is great to see especially from the onset of the project. If this approach is successful, then the reviewer believed that this work could significantly reduce the cost of CF composites, especially after multiple cycles of recover and re-use.

Reviewer 3:

This project is in initial stages, but it clearly leverages Principal Investigators (PIs) ongoing efforts in this area. The reviewer said that the project is well structured and included projected costs estimates.

Reviewer 4:

The reviewer noted that the proposed CF reinforced composites based on bio-based precursors could lead to re-processible and recyclable light-weight composites for vehicle manufacturing. By maintaining fiber integrity across multiple cycles, the average cost of the fiber can be reduced.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, first-year milestones focused on points key to the project goal to facilitate CFRP recycling: feasibility comparison with mechanical performance of an epoxy-base resin completed right away, transition to demonstration and development of recycling commenced. The reviewer also found the progress in synthesis, validation, scale-up, and analysis tasks to be impressive and on track.

Reviewer 2:

The reviewer stated that this project clearly leverages other efforts, and the team delivered outstanding results in the first year.

Reviewer 3:

The reviewer's comment was that good research progress has made in terms of bio-derived resin development, carbon fiber reinforced composite (CFRC) fabrication, a CF recycling study, and initial techno-economic analysis.

Reviewer 4:

The project team has made great progress in synthesizing and demonstrating the concept of the new matrix and its capability to be recycled. The reviewer remarked that the team effectively demonstrated the recycling of a CF composite that shows promising results.

The presentation states that the depolymerization at room temperature takes less than 2 days but can be faster at elevated temperatures. For future commercialization, the reaction would need to be much faster than a day to be attractive to composite recycling companies. After the depolymerization, the reviewer was curious about how the project team envisions the resulting fibers will be reused. For example, if a woven fabric is recovered, the reviewer asked if the weave would remain in its current state as a tight weave or whether it would start to fall apart during the solution process. It will be hard to recover continuous tows of fibers for re-use as a continuous tow since fiber weavers and filament winders typically use spools of fiber that are thousands of feet long, but not that much continuous fiber will be covered from a weave during a batch process. The reviewer wanted to know if the project team could include in the next Annual Merit Review the mechanical testing results to show that the mechanical strength of the fibers is maintained instead of simply stating the integrity is maintained.

The project team offered a good initial TEA and LCA. These analyses are vital to determine the success of this project, so it is great that the project team is already performing the TEA and LCA.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that the collaborators have complementary expertise, with particular focus on redesign, formulation, and recycling area.

Reviewer 2:

The reviewer noted that the project has no partners other than the National Renewable Energy Laboratory (NREL), but the team is collaborating well with other U.S. Department of Energy (DOE) consortia and with wind technology resources at NREL.

Reviewer 3:

This project is in the first year and collaborations have not been established. A list of possible collaborators has been identified. The background of the team in chemistry is impressive. The reviewer encouraged collaboration with organizations having a strong background in composites manufacturing, and technology transition to the industry should be established.

Reviewer 4:

The reviewer remarked that no partners currently exist for the project. However, there are some companies listed that are engaged through the Renewable Carbon Fiber Consortium so there is the potential to add partners throughout the course of the project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The proposed next focus on fiber reuse directly supports the project goals to reduce the effective cost of CF and enable recycling. Future focus on fiber sizing for increased durability was reasonable to the reviewer in terms of pursuing that goal, and demonstration and development of production processes, such as thermo-forming, are key to technology realization. The proposed pivot options of consideration of alternative resins if the current focus resin does not meet requirement helps to strengthen the project potential and mitigate risk.

Reviewer 2:

The reviewer indicated that future work is proposed in a logical manner and includes technical work relevant to the VTO mission as well as analysis of costs, energy, and carbon impact.

Reviewer 3:

The reviewer noted that detailed future research has been proposed with a particular focus on fiber reuse, sizing, and thermo-forming process, as well as scale-up of composite fabrication.

Reviewer 4:

The reviewer asserted that the proposed future research is laid out in a very logical manner and consists of good milestones for scale up, which are an important aspect for demonstration. Additional pathways were mentioned to improve the price and/or greenhouse gas (GHG) emissions, and alternative chemical pathways were presented, which all contribute to the risk mitigation plan for this project. For future work, the reviewer suggested that it would be a good idea to compare to existing composite recycling techniques, such as pyrolysis, which are able to maintain the fiber integrity and recover useful chemicals that decompose during pyrolysis.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that this project supports overall DOE objectives. Specifically, this work could help reduce the cost of CF composites by enabling recycling using a bio-derived matrix. This could help further accelerate the adoption of CF composites in vehicles, thus leading to vehicle lightweighting.

Reviewer 2:

This project clearly addresses key DOE-recognized Critical Challenges identified by seeking to reduce the overall cost of CF through recovery and reuse and by seeking to enable recycling. The developed technology will also address the needs for repair. The reviewer noted that the focus to increase the use of bio-based materials and reduce GHG emissions for vehicle materials, though not identified as critical CFC technology challenges, also supports overall DOE objectives.

Reviewer 3:

The reviewer observed that this work is relevant to the VTO mission and can provide important contribution to the composites community if successful.

Reviewer 4:

According to the reviewer, the project could lead to novel lightweight composite materials for manufacturing of vehicles with lower cost (recyclability) and fuel economy.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources are sufficient for the project team to meet the milestones in a timely fashion. The team has already shown great progress so far with this year’s funds and has a good outline for the future work. So, the reviewer believed the team has the necessary resources to deliver on the rest of the milestones.

Reviewer 2:

Judging from the relatively early point in the project and the significant progress already made, the reviewer commented that this project is on track to achieve its future stated milestones.

Reviewer 3:

The reviewer indicated that the research team has access to all the resources needed to achieve the milestones in a timely fashion.

Reviewer 4:

Resources for this project appeared sufficient to the reviewer.

Presentation Number: mat210
Presentation Title: A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite
Principal Investigator: Patrick Blanchard (Ford Motor Company)

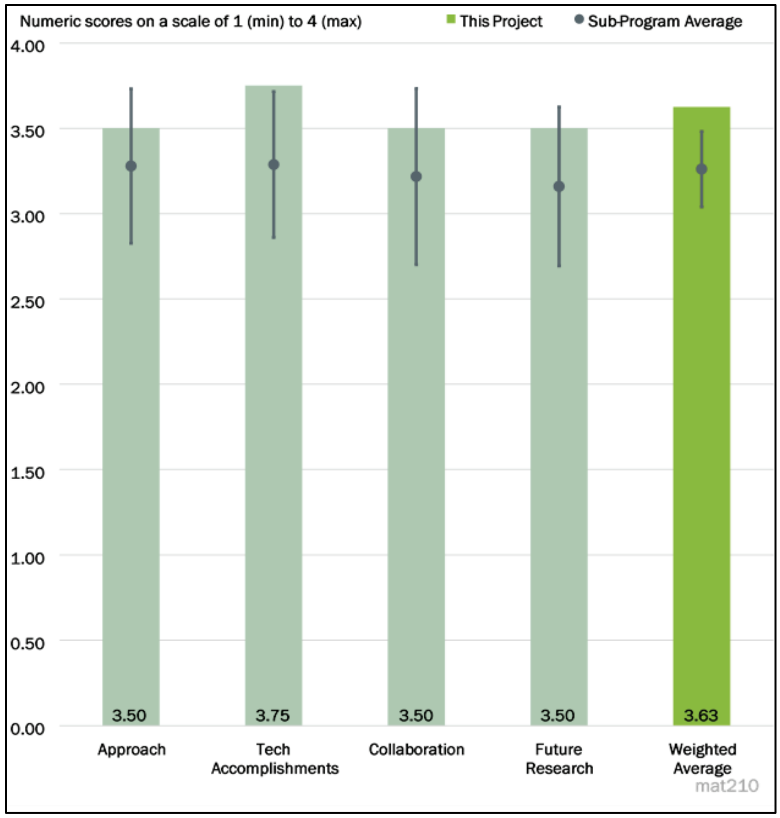

Figure 6-37 - Presentation Number: mat210 Presentation Title: A Novel Manufacturing Process of Lightweight Automotive Seats - Integration of Additive Manufacturing and Reinforced Polymer Composite Principal Investigator: Patrick Blanchard (Ford Motor Company)

Presenter

Patrick Blanchard, Ford Motor Company

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called additive manufacturing (AM) of CF composites with metal inserts for lightweight seats innovative. The project addresses the barriers and makes excellent progress.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer commented that the team did an excellent job in seat design with boundary condition inputs. The design optimization made sense and the project is progressing toward the overall objectives. The metal inserts are necessary. The reviewer inquired whether it is possible to add more CFs in the high stress area to replace metal inserts as this may further reduce the cost and weight.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer noted that collaboration between Oak Ridge National Laboratory (ORNL) and Ford has been excellent. The project is on track to progress toward the stated milestones.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the future work is well planned with appropriate decision points, risk mitigation plans, and pathways to achieving the milestones.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This reviewer asserted that the project directly supports the overall DOE objectives. The success of the project will reduce vehicle weight and carbon emission. The reviewer mentioned that such lightweight seats may find applications in electric vehicles (EVs).

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, ORNL and Ford have sufficient resources and expertise for the project to achieve the stated milestones in a timely manner.

Presentation Number: mat211
Presentation Title: Self-Sensing Self-Sustaining Carbon Fiber-Reinforced Polymer (S4CFRP) Composites for Next-Generation Vehicles
Principal Investigator: Masato Mizuta (Newport Sensors, Inc.)

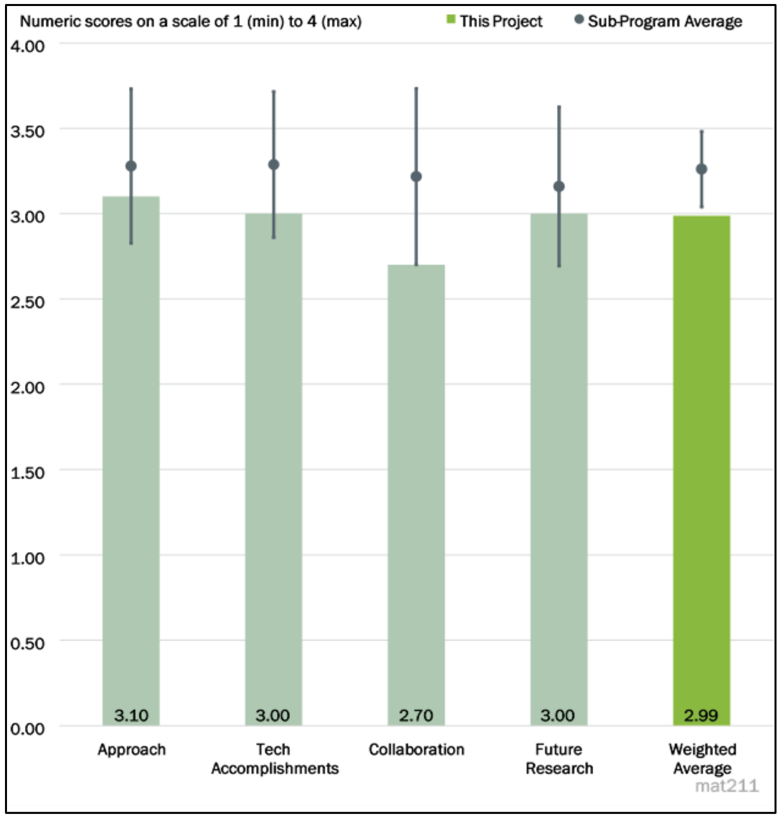

Figure 6-38 - Presentation Number: mat211 Presentation Title: Self-Sensing Self-Sustaining Carbon Fiber-Reinforced Polymer (S4CFRP) Composites for Next-Generation Vehicles Principal Investigator: Masato Mizuta (Newport Sensors, Inc.)

Presenter

Masato Mizuta, Newport Sensors, Inc.

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

Self-sensing structure often requires external energy for generating the impact signal. This project proposes to develop a self-powered, self-sensing structure in CFRP composites. The idea is to place polyvinylidene fluoride (PVDF) piezoelectric material between CF layers and to use CF layers as an electrode. The sensing and energy harvesting are done simultaneously by including the capacitor circuit and pass filter circuit. The reviewer remarked that the idea is novel, and the approach is appropriate.

Reviewer 2:

The approach addressed the issue of how to integrate sensing functionality into a CFRC. It was demonstrated that the composite could serve as a damage detection device as well as an energy harvester. A circuit was developed that could function as both a sensor and energy harvester. However, the reviewer commented that this was a fairly rudimentary approach to integrating a sensor into a composite since just a layer of PVDF was placed between layers of CF fabric.

Reviewer 3:

The reviewer praised the approach described for developing a multifunctional polymer composite material as excellent because it includes a proven sensor technology but uses the conductive CF as electrodes to transform the sensor output to a damage detection output. The components are commercially available, which reduces costs and the risk of developing a system that does not meet the technical barriers. The development sequence and the circuit layout are well designed and very feasible for successfully addressing the technical barrier of real-time damage identification. The technical barrier for high fiber cost was not addressed during Phase I but is specified as part of the Phase II effort, if funded.

Reviewer 4:

The experimental test program appeared to the reviewer to validate feasibility of the technical approach with impact detected using the integrated piezoelectric sensor. Several questions remain regarding connectivity to the sensors and compatibility of the techniques with automotive production processes. However, this is out of scope for the current project.

Reviewer 5:

The reviewer stated that this project seeks to reduce damage inspection difficulty for CFRP. The project demonstrated that CF fabrics could be assembled into a laminate composite that produces an electric signal when it experiences an impact. The reviewer asserted that the translation of this demonstration to CFRP components used on vehicles or of the impact detection to condition monitoring methods was not provided in this early-stage exploratory research.

CF, though expensive and energy intensive to produce, is of interest for lightweighting automotive parts because of its excellent mechanical properties. Use of CF as electrodes in the demonstrated impact sensor is disconnected from use of CF as mechanical reinforcement in automotive components. The impact or other damage sensing needs to be demonstrated using an automotive CFRP to be relevant or, alternatively, the sensing technology could be pursued as a coating or thin layer to be applied to automotive composites to track impact. In that case, it does not need to be composed of CF itself, as CF on the vehicle is for mechanical reinforcement, not for use as electrodes. The reviewer opined that the project might have been better designed if it considered or at least better communicated how the CF-PVDF sensors would be incorporated in a vehicle to meet DOE non-destructive evaluation (NDE) targets.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that the presentation showed clear evidence of feasibility for impact, damage detection, and energy harvesting.

Reviewer 2:

For the very short period of performance (about 9 months), this reviewer observed significant technical accomplishments because the project team demonstrated that the sensor, which was integrated into the CFRP material, could detect shock and vibration and generate an electric signal with different frequency characteristics for shock and vibration. However, the charged power storage (energy harvesting feature) was unable to trigger the damage-detection circuit although the ambient vibration signal was sufficient to power the circuit, so this is a very positive result. The reviewer suggested that more research will be needed to select a sensor with the sensitivity and output to perform this function.

Reviewer 3:

The reviewer remarked that the project successfully met its stated objectives of designing and demonstrating a sensor that detects impact. The objective of energy harvesting was demonstrated, but it was not clear whether sufficient energy is harvested to enable the impact sensing or over what time period it is active. This reviewer also reported that "multifunctional CFRP composite including circuitry hardware and software" targeted was demonstrated as a laminated of CF weave and PVDF with externally applied laboratory signal sensing.

Additionally, the reviewer commented that the PVDF composite was multifunctional in the sense that it both produced a voltage from repetitive low-level mechanical stimuli (energy harvesting) and from discreet, higher level mechanical stimuli (impact detection). The functions of energy harvesting and sensing are valuable for on onboard sensor, but the role of CF on a vehicle is mechanical reinforcement and the reviewer would have expected a multifunctional CFRP composite to provide a mechanical (structural) function as well as other useful functions, such as energy storage or sensing.

Reviewer 4:

The reviewer indicated that the team fabricated the composites with PVDF piezoelectric materials and showed the impact-sensing signals with self-power generation. It was not clear to the reviewer if the sensing is a damage detection or an impact detection. The reviewer asked about how the signals differ between an impact without causing damage and an impact with damage. Also, it is not clear if the capacitor circuit and the high pass filter circuit are embedded in the composite structure or they are separate from the composite, since the team mentioned "… fabricate the multifunctional CFRP composites including circuitry hardware.…" Overall, the objectives were achieved in this project.

Reviewer 5:

This reviewer reported that all milestones were met. The team demonstrated the multifunctional composite fabrication as well as the energy harvesting and damage detection functionalities. While the milestones were met, the results reported were not exceptional compared to other sensors that have been demonstrated. It was stated that a novel circuit was developed for this work, but the circuit was not really discussed so the novelty of it could not be determined by the reviewer.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Although this is a short-term Small Business Innovation Research (SBIR) project, the reviewer described potential collaboration identified for future research as outstanding because it includes a full spectrum of entities (researchers, Tier 1 suppliers, and an automotive OEM). The reviewer found apparent close coordination during the planning phase.

Reviewer 2:

According to the reviewer, the PI has reached out to automotive original equipment manufacturers (OEMs) and suppliers to understand customer requirements and interest in future development.

Reviewer 3:

The reviewer stated that no collaborations or partners were named on this project. It was mentioned that OEMs and Tier 1 suppliers were interested in the technology, but no partners have been established yet.

Reviewer 4:

There is no collaboration outside the company, but the reviewer said that the team successfully completed the project.

Reviewer 5:

This reviewer stated that there are no team partners; potential collaboration and communication with OEMs, suppliers, etc., is envisioned but has not been pursued.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer reported that the proposed research plan contains a logical pathway that scales up in complexity to address concerns related to real-world applications. There are also provisions to account for the use of more sustainable composite reinforcements.

Reviewer 2:

The reviewer commented that because this is a Phase I SBIR project, the proposed future research to add a novel sensor to enhance the reliability for in situ damage detection and location is a logical step for Phase II funding, if available. The reviewer called the proposed future research to add a natural fiber to the polymer composite to reduce cost questionable. Although adding a natural fiber will reduce cost, the physical and structural properties of the polymer composites are typically degraded.

Reviewer 3:

This reviewer said that the project has ended.

Reviewer 4:

According to the reviewer, the project has ended.

Reviewer 5:

The reviewer indicated that the project has ended.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project supports the requirements identified by DOE Advanced Research Projects Agency-Energy (ARPA-E) for multifunctional composite materials for energy storage in structural load paths to make a step change in vehicle energy efficiency, particularly for autonomous vehicles and EVs. This project also supports the VTO Materials Technology R&D Program for vehicle weight savings by using integrated lightweight sensors in automotive components.

Reviewer 2:

Overall DOE objectives include enabling lightweight vehicles through development of NDE to track, predict, and extend CFRP lifetime. The reviewer commented that this project supports that objective with early-stage demonstration of a sensor concept that might be self powering and provide indication of CFRP damage in use.

Reviewer 3:

The reviewer stated yes and explained that one of the concerns of using CFRP by replacing metal is its brittle fracture behavior. CFRP is susceptible to a crack failure without noticing its prior damage. A self-damage detecting composite will facilitate the use of the composite.

Reviewer 4:

The reviewer indicated that integration of sensing capability is a key enabler to the incorporation of composite solutions in safety critical applications.

Reviewer 5:

The reviewer stated that this project meets a DOE objective of integrating in situ sensing into composite structures in vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, the funding of $200,000 to investigate simultaneous sensing and vibration energy harvesting as part of a multifunctional CFRP composite by the small research team is sufficient for this 9-month SBIR project.

Reviewer 2:

The reviewer indicated that the objectives of the project were completed with the resources available.

Reviewer 3:

The reviewer commented that the resources provided for this project were sufficient to meet the milestones established for the project.

Reviewer 4:

The reviewer said that the funding was sufficient to develop the technologies.

Reviewer 5:

The reviewer remarked that the project is complete.

Presentation Number: mat212
Presentation Title: Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles
Principal Investigator: Amrita Kumar (Acellent Technologies, Inc.)

Presenter

Amrita Kumar, Acellent Technologies, Inc.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

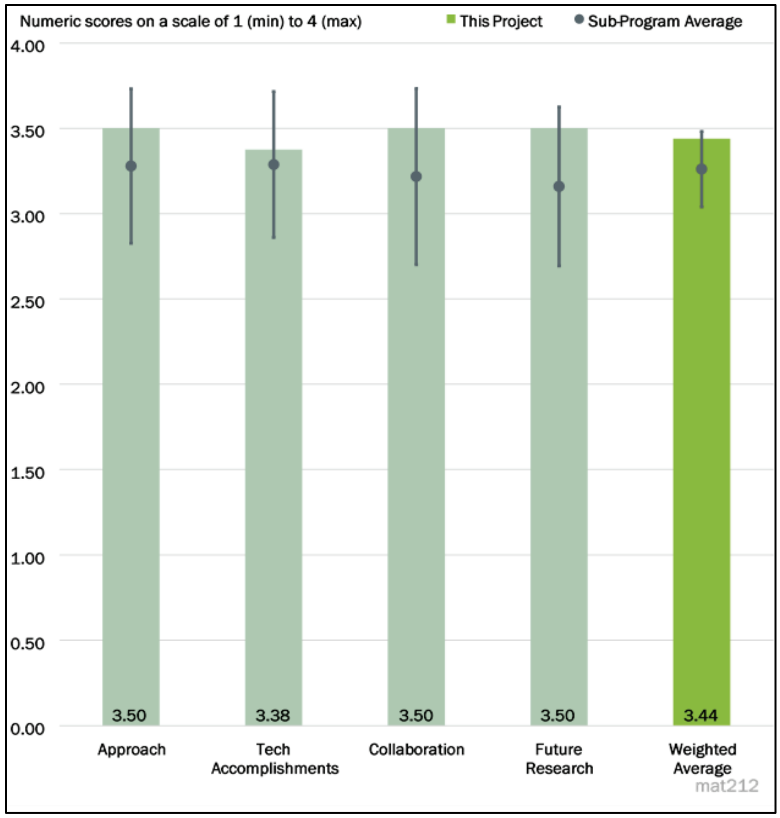

Figure 6-39 - Presentation Number: mat212 Presentation Title: Integrated Self-Sufficient Structurally Integrated Multifunctional Sensors for Autonomous Vehicles Principal Investigator: Amrita Kumar (Acellent Technologies, Inc.)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer found that the approached for this project was good in that it looked at both active and passive sensing for both a pedestrian protection system and battery monitoring system. The project focused on creating a sensor suite that could be integrated into a vehicle. This addressed technical barriers in creating a system that could be integrated into a vehicle.

Reviewer 2:

The approach is to develop a sensor system utilizing embedded sensor networks designed into vehicle structures to provide weight savings through integration of materials with sensors, electronics, and batteries; to minimize parts counts; and to improve manufacturing processes that will enable significant cost savings. The system under development includes an integrated impact detection system in the front bumper of a car and a battery monitoring system. System integration during the manufacturing process is intended to create a structurally integrated sensor network. The reviewer commented that an integrated approach for both systems will achieve the technical targets identified by DOE ARPA-E for multifunctional composite materials for energy storage in structural components in future vehicles. The approach also supports the VTO Materials Technology R&D Program goals for vehicle weight savings by using integrated lightweight layered sensors in structural elements of a vehicle.

Reviewer 3:

The reviewer noted that the work plan addresses all key challenges and offers practical solutions for implementation.

Reviewer 4:

The project is a good combination of sensor development and design integration of a pedestrian protection system (PPS) and a battery management system (BMS) for autonomous vehicles and EVs. The approach taken by the project toward the goals is clear, and the progress made is commensurate with the timeline. The parts have been fabricated and tested.

The reviewer had several questions and comments:

- Because the interest is in monitoring structures for damage or actuation, what are the unique testing methods beyond what have been employed so far that can also be geared toward performance over longer periods of time? Can there be aging experiments done to look at sensor response degradation?
- There are a number of opportunities for materials development, too. What is the correlation between specific materials development approaches and their demonstrated sensor design in various thermoplastic and thermoset composites?
- What artificial intelligence (AI) methods may be employed that can be specific to improving sensor performance?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

For the very short period of performance (about 9 months), the reviewer asserted that there has been excellent progress for designing and installing a sensor network for pedestrian impact detection. Acellent and Stanford University also used piezoelectric transducers to accurately monitor the state of charge and end of life for battery cell monitoring when the sensors were embedded inside a composite structure. These are significant accomplishments for the short-term effort toward meeting the technical targets.

Reviewer 2:

All milestones were met for this project. At least two additional functionalities were integrated into vehicle composites. In the pedestrian protection system, the project team was able to demonstrate both a pedestrian and non-pedestrian impact event as well as provide image location information. The reviewer commented that good information was provided about how the sensors were fabricated and integrated into an actual bumper for testing. The project team demonstrated that the response time to an impact could be minimized by integrating an array of sensors as opposed to a single sensor that is currently used.

Reviewer 3:

According to the reviewer, the technical accomplishments match the key performance indicators very well. The demonstrated sensor integration and design are what has been proposed. The barriers of the project have been clearly identified. The partnership with Stanford and Ford is very productive. The reviewer suggested that more collaborative efforts with possible other external partners could be started.

Reviewer 4:

The presentation shows clear evidence to the reviewer that the sensing system under development can be very effective at detecting impact and, potentially, defects in composite components.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer applauded as excellent this small, collaborative project team, which includes a university, a supplier of commercial systems, and an OEM, all of whom are essential for a successful transfer of technology. This team exemplifies elements needed for acceptance of a multifunctional, structurally integrated sensor system by an automotive manufacturer.

Reviewer 2:

The reviewer commented that the PI has been extremely proactive in seeking guidance from existing industrial partners in order to fully understand downstream customer requirements.

Reviewer 3:

The project team collaborated with Stanford University and Ford. These were excellent partners for the project in that the project team utilized licensed technology from Stanford for the BMS as well as developing requirements for the systems from Ford. The reviewer stated that this provides a strong case for future deployment in future vehicles.

Reviewer 4:

The reviewer suggested that a new collaborative effort with possible external partners be started in the testing phase beyond PPS and BMS. This reviewer also noted focus on materials durability.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Since this is a Phase I SBIR project, the proposed future research for Phase II, if funded, is to develop a PPS and a BMS using a unified architecture for implementation of both systems in a vehicle design. The reviewer said that this is a logical follow-on to Phase I. Future research proposed includes designing, developing, and testing of complete prototype systems; designing the architecture of a unified multifunctional sensing system for cars; and developing commercialization plans and cost targets with automotive companies. This is an outstanding approach to achieve transfer of the systems under development.

Reviewer 2:

The direction toward future research was clear to the reviewer and has been stated in the presentation well. This is appropriate to the current Technology Readiness Level (TRL) level. It is possible that a new direction toward unique geometries of the part and environmental testing methods can be employed.

Reviewer 3:

The reviewer commented that the proposed future research promises to address most of the scaling issues as well as highlighting implementation challenges that may remain unknown.

Reviewer 4:

The reviewer noted that the project has ended, but Phase II work has been proposed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer responded affirmatively that the project is relevant to the mission of the DOE Energy Efficiency and Renewable Energy (EERE) VTO. It also addresses the challenges of the specific TRL level that is addressed from the phased project timeline.

Reviewer 2:

The reviewer said that this work supports development of composite materials applications, which in turn support more energy efficient transportation applications.

Reviewer 3:

The reviewer agreed that this project supports the DOE objectives of needing multifunctional composites to be integrated into the vehicle structure to reduce the weight of conventional components.

Reviewer 4:

This project supports the requirements identified by DOE ARPA-E for multifunctional composite materials for energy storage in structural load paths to make a step change in vehicle energy efficiency, particularly for autonomous vehicles and EVs. According to the reviewer, this project also supports the VTO Materials Technology R&D Program goals for vehicle weight savings by using integrated lightweight layered sensors in structural elements of a vehicle during manufacture.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, the funding of $200,000 to investigate self-sufficient, integrated, multifunctional sensors embedded in thin dielectric films for automotive applications by the small research team is sufficient for this 9-month SBIR project.

Reviewer 2:

The reviewer said that the objectives of the project have been completed with the resources made available.

Reviewer 3:

The resources were sufficient to deliver on all the proposed milestones in the proposed timeframe, according to the reviewer.

Reviewer 4:

The reviewer responded positively that the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly, which may be an impediment to reaching the milestones.

Presentation Number: mat213
Presentation Title: Active Monitoring of Composite Structures through Embedded Synthetic Fiber Sensor
Principal Investigator: Halina Tran (Intellisense Systems Inc.)

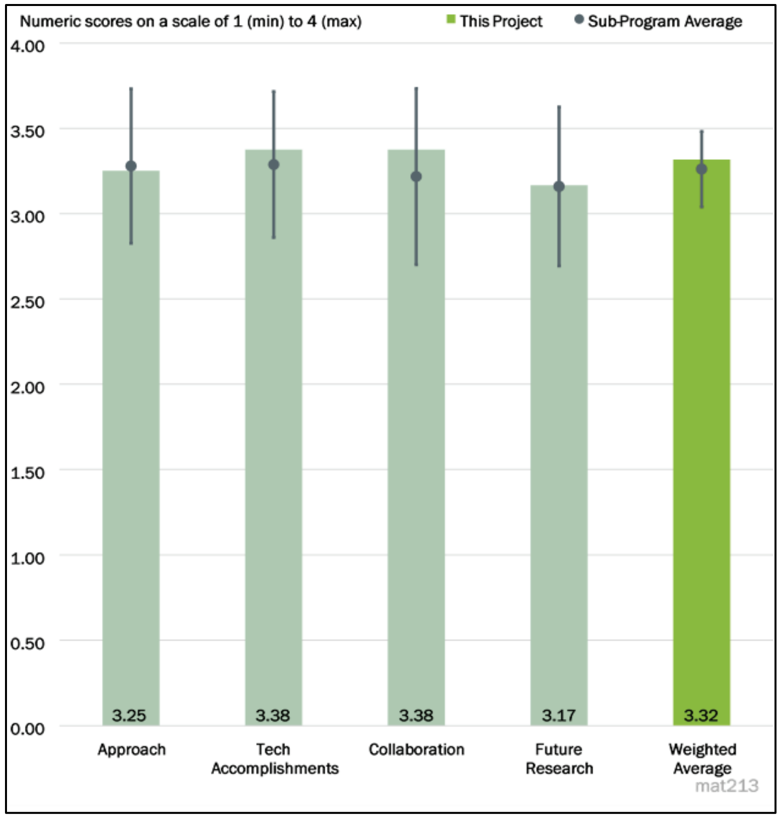

Figure 6-40 - Presentation Number: mat213 Presentation Title: Active Monitoring of Composite Structures through Embedded Synthetic Fiber Sensor Principal Investigator: Halina Tran (Intellisense Systems Inc.)

Presenter

Halina Tran, Intellisense Systems Inc.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The idea of placing thermoplastic functional fibers as sensors in the composite structure is novel as it has advantage of saving mass. Also, the reviewer indicated that the technology is being applied to many civil engineering applications.

Reviewer 2:

The reviewer stated that the primary objective in evaluating the potential of embedded sensors has been demonstrated per the original work plan.

Reviewer 3:

This reviewer remarked that the work is a good combination of sensor development and design integration in the structure or part monitoring research of the Materials Technology R&D Program. The approach taken by the project toward the goals are clear and the progress made is commensurate with the timeline. The parts have been fabricated and tested.

The reviewer offered the following questions and comments:

- Because the interest is in monitoring structures for damage or failure, what are the unique testing methods beyond what have been employed so far that can also be geared toward performance over longer periods of time or extreme conditions? Can there be aging experiments done to look at sensor response degradation? Or use of more environmentally challenging factors?

- There are a number of opportunities for materials development too beyond nylon. What is the correlation between specific materials development approaches and their demonstrated sensor design in various thermoplastic and thermoset composites beyond nylon?
- What, if any, AI or simulation methods may be employed that can be specific to improving sensor performance?

Reviewer 4:

This reviewer explained that in order to detect a mechanical deformation, the team developed a sensing fiber. In this project, the team embedded their sensing fibers in a CF mat and performed mechanical tensile, impact, and environmental tests. The approach was well designed. However, it was not clear to the reviewer what technical challenges the team overcame. It is not clear if the development of a sensing fiber itself was a part of this project or only the mechanical tests were done in this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The work presented showed the reviewer clear evidence of meeting the agreed-upon technical milestones. The ability of sensors to provide feedback to external events, such as strain, impact, and temperature, shows potential for the technology moving forward.

Reviewer 2:

The reviewer commented that the team has assembled test coupons and tested the response of functional fibers embedded in woven CFRPs. Improved manufacturing method has been conceptualized. During testing, the sensor fibers follow the strain readings within approximately 0.3% strain.

Reviewer 3:

According to the reviewer, the technical accomplishments match the key performance indicators very well. The demonstrated sensor integration and design are what has been proposed. The barriers of the project have been clearly identified.

Reviewer 4:

This reviewer noted that the team successfully weaved the sensing fibers in the CF mat and performed various types of mechanical tests. The team has verified that the reading from the sensing fibers followed the strain applied. However, the graph of tensile test shows that the strain (blue line) does not seem to match the resistance (reading – black line). If not matching, the reviewer indicated that a non-linear relationship between the strain and the reading should have been investigated, but it was not presented in the poster. Based on the test results (thermal test, impact test, and tensile test), the team developed an algorithm to automatically detect impact events.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer indicated that the team is collaborating with the University of Southern California (USC), which is an excellent team member.

Reviewer 2:

Per the original project objectives, the reviewer remarked that the team has work effectively in both developing the technology and producing samples for testing at M.C. Gill Composites Center.

Reviewer 3:

The reviewer noted that the PI's team collaborated with the USC, which fabricated the test coupons and performed mechanical tests.

Reviewer 4:

The reviewer proposed that more collaborative efforts with possible other external partners be started.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that the proposed work is a logical progression of current research that aims to address scaling challenges as well as longer term quality and robustness concerns.

Reviewer 2:

The reviewer said that the project (Phase 1) has ended.

Reviewer 3:

The team developed an algorithm that can automatically detect impact events and determine mechanical properties. The reviewer suggested that this needs to be integrated in scaled-up manufacturing of parts.

Reviewer 4:

There is a need to carry the project to a higher goal, if possible, especially in materials development. The direction for future research was clear to the reviewer and has been stated in the presentation well. The work is currently appropriate to the lower TRL level. It is possible that even at this level a new direction toward new materials and unique geometries with environmental testing methods can be employed.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer responded affirmatively that the project is relevant to the mission of the DOE EERE VTO. It also addresses the challenges of the specific TRL level that is addressed in the phased project timeline.

Reviewer 2:

The reviewer indicated that embedded sensing is a key enabler to enhanced feature content in lightweight composite structures.

Reviewer 3:

The reviewer responded affirmatively and said that one of the concerns of using CFFP instead of metal is its brittle fracture behavior. CFRP is susceptible to crack failure without noticing its prior damage. An impact-detecting composite will facilitate the use of the composite.

Reviewer 4:

The reviewer commented that a lightweight multifunctional composite is desired for vehicle applications. Saving mass while incorporating advanced safety features can be accomplished if functional composites are deployed.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources allocated appeared to the reviewer to be appropriate for the work completed.

Reviewer 2:

The reviewer said that the funding amount is sufficient to develop the technologies.

Reviewer 3:

The resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly, which may be an impediment to reaching the milestone. It is possible that more materials development can be carried out at this stage beyond the current nylon, but the reviewer opined that this may require more resources.

Reviewer 4:

The reviewer stated that the project has ended.

Presentation Number: mat214
Presentation Title: Multifunctional Composites for Vehicles
Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

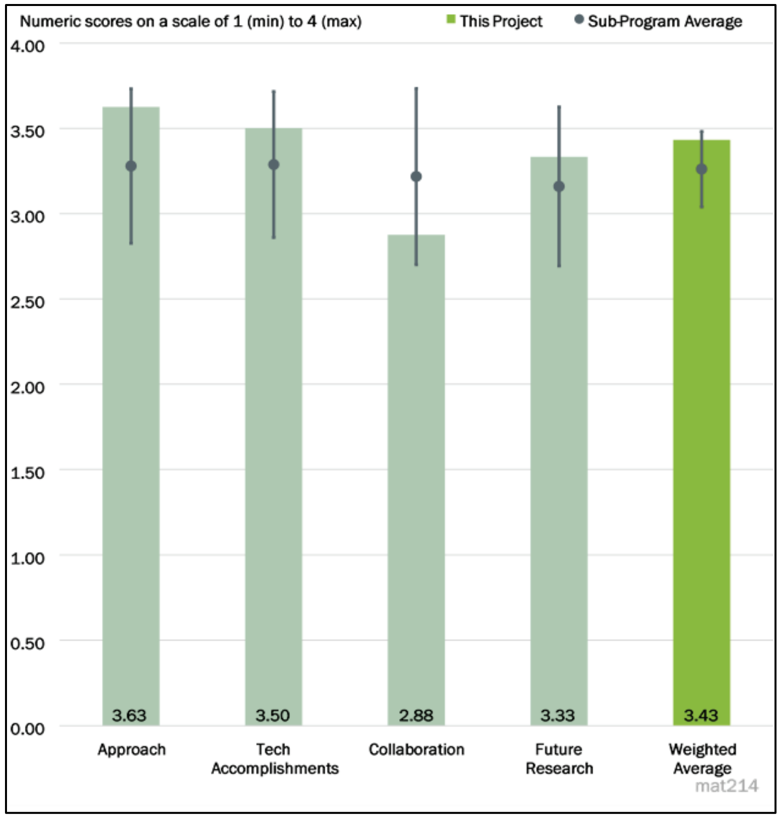

Figure 6-41 - Presentation Number: mat214 Presentation Title: Multifunctional Composites for Vehicles Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

Presenter

Henry Sodano, Trimer Technologies, LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This was an excellent approach to integrate sensing, electromagnetic interference (EMI) shielding, and enhanced thermal conductivity into composites. The laser-induced graphene (LIG) technique is a unique approach to integrate additional functionalities into thermoplastic composites. According to the reviewer, this approach really overcomes the technical barriers of cost-effectively integrating sensors into composites while also enhancing the strength.

Reviewer 2:

The reviewer reported that the objective of this project is to manufacture a composite material including three functionalities—strain sensing, EMI shielding, and improving thermal conductivity. The approach to the objective includes optimizing the graphene array and density, optimizing processing parameters for the graphene structure, manufacturing composite panels, and testing mechanical, thermal, and EMI properties. The reviewer found the approach to be well designed, and the team showed the results that can lead to sensor and protection applications.

Reviewer 3:

The reviewer remarked that multifunctional composites exhibiting EMI shielding, strain sensing capability, and high specific strength and stiffness have been designed by use of graphene-based materials. These materials are expected to be cheaper than that of the carbon nanotubes (CNTs).

Reviewer 4:

The work is a good combination of sensor development and design integration in structure monitoring research with graphene as an active material in the Materials Technology R&D Program. The approach taken by the project toward the goals was clear to the reviewer, and the progress made is commensurate with the timeline. The parts have been fabricated and tested.

The reviewer presented the following questions and comments:

- Because the interest is in monitoring structures for damage or actuation with electromagnetic (EM) shielding, what are the unique testing methods beyond what have been employed so far that can also be geared toward performance over longer periods of time? Can there be aging experiments done to look at sensor response degradation?
- There are a number of opportunities for materials development too with other nanomaterials. What is the correlation between specific materials development approaches and their demonstrated sensor design in other nanomaterials like carbon nanotubes (CNT)? Are there other thermoplastic and thermoset composites to use?
- What are some possible simulation and AI methods that may employed that can be specific to improving sensor performance?

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This reviewer explained that within just a short timeframe for this project, many different functionalities from static and fatigue sensing to EMI shielding and thermal conductivity have all been demonstrated for this LIG technology. The ability to tailor the LIG geometry was also demonstrated, which the reviewer commented really opens up many possibilities for different sensor designs.

Reviewer 2:

The reviewer noted that composites with strain-dependent electrical resistivity were developed, and such composites perform as a strain sensor. Capacitive-based touch sensors were developed, and those can measure strain.

Reviewer 3:

The technical accomplishments matched the key performance indicators very well. The demonstrated sensor integration and design are what has been proposed. The barriers of the project have been clearly identified. The different oxidation states of graphene are another variable. Also, the reviewer asked whether this oxidative stability changes with time and how they will be studied. The reviewer suggested that more collaborative efforts with possible other external partners could be started.

Reviewer 4:

The team has shown the effect of graphene length and process parameters on the resistivity. Also, the team designed the strain sensor using the material and showed a linear response from a mechanical deformation. The team showed the EMI shielding performance and, although not included in the original Objective section, showed a touch sensing capability. The project accomplished most of the objectives. A question from the reviewer to the team is about a thermal conductivity performance, which is in the Objective section. The conductivity result was not shown in the Accomplishment section.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer found that there was great collaboration with TPI Composites and Toyota. Working closely with both a composites company and an automotive company will help bring this technology to the market faster.

Reviewer 2:

The reviewer noted that this is a single PI project. The PI worked with Rhein Tech Laboratories to measure EMI shielding effectiveness.

Reviewer 3:

The reviewer suggested that more collaborative effort with possible other external partners could be started.

Reviewer 4:

Although several partners were listed, this reviewer found no collaboration described in the poster.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The project is nearing the end, but the team has proposed some great work on making it a wireless sensor. The reviewer believed that the technology has excellent risk mitigation by having many different added functionalities to the composite.

Reviewer 2:

The direction of future research was clear to the reviewer and has been stated in the presentation very well. This is appropriate to the current TRL level. However, it is possible that a new direction for various oxidation states and clusters of graphene including environmental and stress testing methods can be employed.

Reviewer 3:

The project is 90% done, and it is ending. The reviewer noted that the PI is planning to apply wireless sensing capability.

Reviewer 4:

The project (Phase 1) has ended. According to the reviewer, the future research described in the poster is not for this phase of research but for the next phase if any additional funding is provided.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer responded affirmatively that the project is relevant to the mission of the DOE-EERE-VTO and the United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability (U.S. DRIVE). It also addresses the challenges of the specific TRL level that is addressed in the phased project timeline.

Reviewer 2:

According to the reviewer, not only does this project support DOE objectives, but it also offers a unique approach to integrating sensing, EMI shielding, and improved thermal conductivity to create multifunctional composites for automotive composites.

Reviewer 3:

The reviewer affirmed that a composite material with sensing capability that can be manufactured via a thermoplastic molding technique can facilitate the use of thermoplastic and help reducing the weight of vehicle components.

Reviewer 4:

The reviewer observed that multifunctional materials are needed for lightweight structures that can also sense applied stress or strain.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

With all the progress made, it was clear to the reviewer that the resources are sufficient to meet the milestones of the project in the proposed timeframe.

Reviewer 2:

The reviewer said that the funding amount is sufficient to develop the technologies.

Reviewer 3:

The reviewer responded affirmatively and said that the resources for the project and milestones to be achieved are sufficient at this specific point of the project. The barriers have been identified clearly, which may be an impediment to reaching the milestone. Further studies on new materials are possible, but the reviewer acknowledged that this may move the milestones' goal posts.

Reviewer 4:

The reviewer stated that the project has ended and met the goal.

Presentation Number: mat215
Presentation Title: Short Fiber Preform Technology for Automotive Part Production - Phase II
Principal Investigator: Dirk Heider (Composites Automation, LLC)

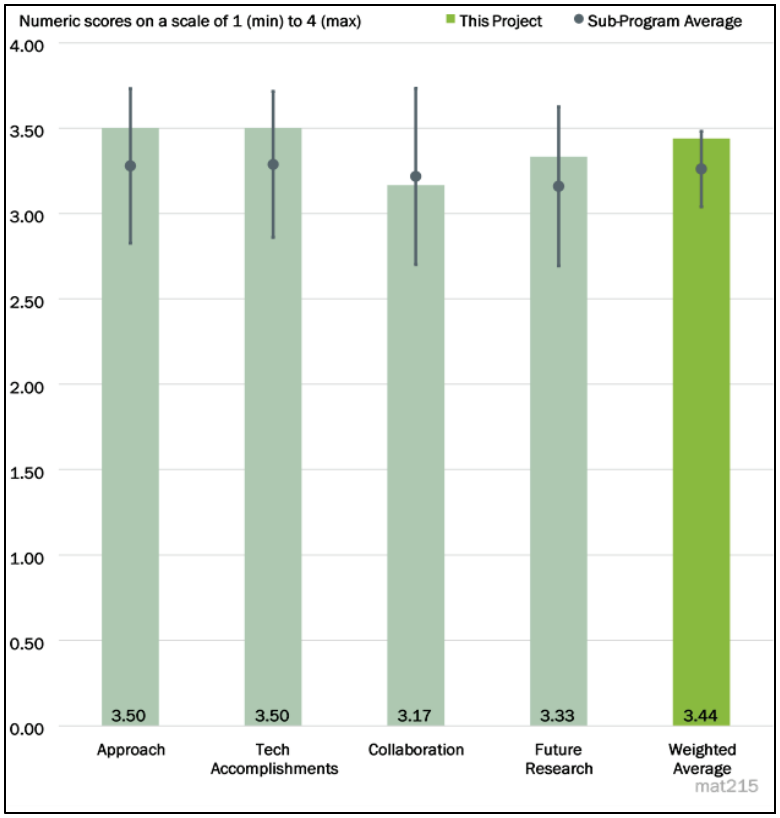

Figure 6-42 - Presentation Number: mat215 Presentation Title: Short Fiber Preform Technology for Automotive Part Production - Phase II Principal Investigator: Dirk Heider (Composites Automation, LLC)

Presenter

Dirk Heider, Composites Automation, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer opined that the technical project provides a clear pathway from early concept development to concept prove-out. The work also does a good job at leveraging recent advances in CF recycling.

Reviewer 2:

This reviewer indicated that the current critical challenges for CFRP addressed by this project include low-cost high-volume manufacturing, low-cost fibers, and recycling (OFFAL/Vehicle). The reviewer commented that the project appropriately sought to demonstrate that the tailorable universal feedstock for forming (TuFF) net pre-form generation process enables effective use of low-cost virgin CF, scrap CF, and recycled CF in high-volume fraction composites with competitive performance. Investigation of fiber orientation and fiber length distribution in resulting composites was also part of the good project design.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found that excellent progress has been reported on tasks to date, including demonstration of the process with different fiber sources, demonstration of formability, and assessment of composite performance and resulting fiber microstructure.

Reviewer 2:

The reviewer indicated that the technical project has clearly demonstrated the potential of the new recycled CF format. This has been validated through experimental studies and subsequent mechanical testing.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, excellent cooperation appears to have occurred between Composite Automation and team members (University of Delaware and Vartega). Other promising contacts are mentioned or targeted with Zoltec, Hexion, Barnet, Institute for Advanced Composites Manufacturing Innovation (IACMI), U.S. Automotive Materials Partnership (USAMP), OEMs, and suppliers.

Reviewer 2:

All aspects of the project showed evidence of excellent coordination to the reviewer as the support of several project partners has been required to complete the work to date.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The key challenges to the "paradigm shift in composite processing" proposed by this project seems to be cost and throughput of conversion of received fibers into stabilized pre-forms ready for part production. The reviewer indicated that Proposed Future Research appropriately targets these challenges through focus on scale-up, automation, cycle time, rate, and cost benefits.

Reviewer 2:

The reviewer said that the next phase of the project addresses the majority of open issues while also securing engagement with prospective customers.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that effective methods to translate recovered and recycled fiber into equivalent-performance composites clearly support DOE efficiency objectives.

Reviewer 2:

The reviewer said that the project develops a low-cost source of carbon fiber materials from recycled feed stocks.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the project has been completed within the current resource plan.

Reviewer 2:

The reviewer commented that the level of remaining project resources is not reported.

Presentation Number: mat216
Presentation Title: Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites - Phase II
Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

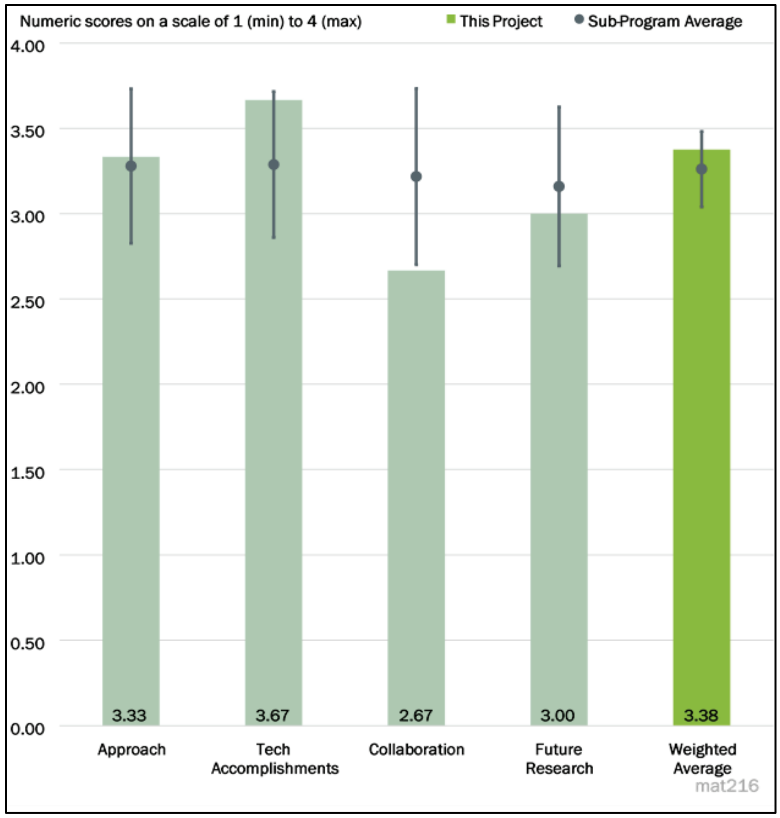

Figure 6-43 - Presentation Number: mat216 Presentation Title: Low Cost Resin Technology for the Rapid Manufacture of High-Performance Fiber Reinforced Composites - Phase II Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

Presenter

Henry Sodano, Trimer Technologies, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 67% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 33% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

A low-viscosity resin system with the capability of being cured at 140 degrees Celsius (°C) within 30 seconds (s) has been developed for efficient infusion and composite product manufacturing. The approach has not been shared in detail for proprietary reasons, but the involvement of TPI and IACMI Scale-Up Research Facility (SURF) was very encouraging to the reviewer.

Reviewer 2:

The reviewer noted that the Technical Barriers identified for this project are lack of cost-effective systems and designs, joining technologies for CFRP, and fiber and resin bond strength. The first two barriers correspond to the DOE Critical Challenges of Low-cost High-volume manufacturing and Joining. The third barrier, insufficient fiber and bond strength, may be important, but it is not mentioned in the USDRIVE Materials Technical Team (MTT) Roadmap 2017, Section 6, as referenced.

This project primarily supports the target of low-cost, high-volume manufacturing through development of a resin with very rapid cure time, even for thick components. According to the reviewer, nothing in the project poster describes any benefit of the resin technology being developed for addressing the need for multi-material CFRP joining methods or for improving fiber and resin interfacial strength.

The focus on fire resistance of the polymer under development may be important for EV battery casings but does not address an identified barrier for automotive lightweighting. The reviewer said that the strategy of the project to compare a long list of the fast-cure resin material properties with incumbent materials, to initially investigate environmental stability, and to evaluate thermal performance is well placed. Furthermore, the reviewer indicated that evaluating the resin in a CFRP is a reasonable project scope component that appears to be missing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The composites were successfully cured within 30 s, an accomplishment the reviewer found to be outstanding.

Reviewer 2:

The reviewer opined that excellent mechanical, thermal, and kinetic performance of the resin is demonstrated, which may be considered a technical accomplishment and progress. Evaluation versus proposed or planned targets is difficult with any list of milestones or deliverables. Technical targets appear to be the only similar information provided. Against these, no progress has been demonstrated addressing multi-material joining or improvement of fiber and resin bond.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer remarked that TPI and IACMI are involved, and they are scheduled to process parts at SURF this summer.

Reviewer 2:

This reviewer reported that IACMI-SURF and TPI Composites are listed as team partners, but no information was provided describing their contributions relative to Trimer Technologies or collaboration and coordination among the partners. Fatigue testing was apparently performed in collaboration with unnamed OEM partners, and fiberglass panels were burn tested at Test Corp.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer suggested that scalability needs to be demonstrated, and that is what is already planned. However, the project has officially ended.

Reviewer 2:

The Future Research section communicates that commercialization of the Trimer resin will require extensive process development and material testing. Also, internal mold release agents, scale-up of the manufacturing process, and component level testing are mentioned as needs for commercial adoption. The reviewer indicated that this description does not constitute a plan, incorporate decision points, or consider risk mitigation strategies.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that the project supports DOE objectives. Lightweight materials from polymer composites capable of being formed in less than 1-minute (min) cycle are needed.

Reviewer 2:

This reviewer commented that fast-cure, high-performance thermoset resins could be a key enabling technology for low-cost, high-volume manufacturing and increased use of lightweight CFRPs. Achieving low-cost, high-volume manufacturing will require not only rapid cure times, but also affordable resin. The reviewer indicated that cost information and cost targets for the Trimer resin are not provided for comparison with the state of the art.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the team has already met the goals and the project has ended.

Reviewer 2:

The reviewer found that it was impossible to assess if remaining resources are sufficient to complete the remaining milestones because neither remaining budget nor remaining milestones have been communicated.

Presentation Number: mat217
Presentation Title: New Higher Temperature Performance Alloys (1A2)
Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

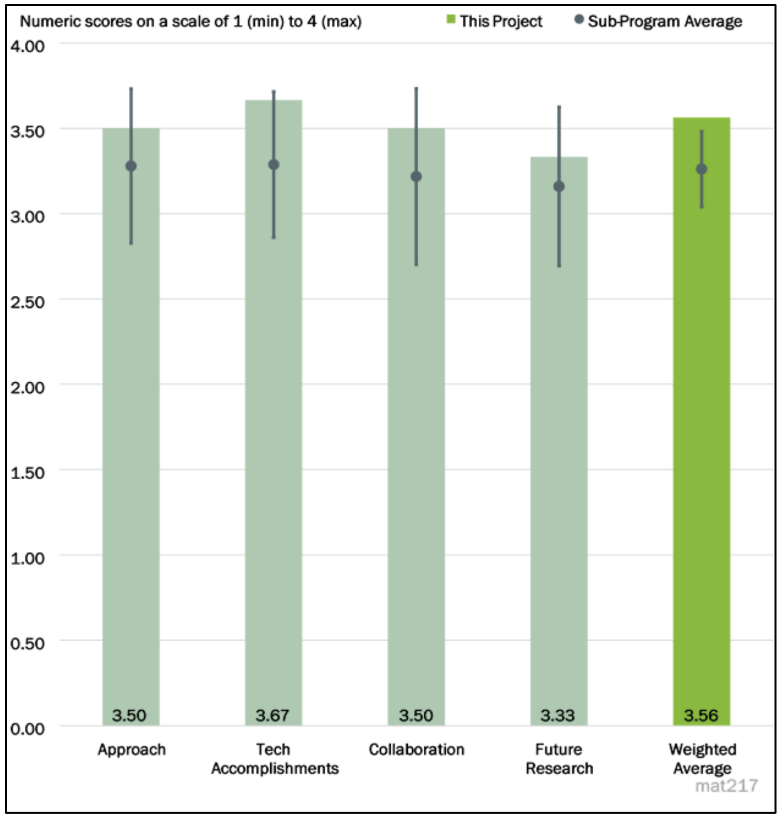

Figure 6-44 - Presentation Number: mat217 Presentation Title: New Higher Temperature Performance Alloys (1A2) Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

Presenter

Amit Shyam, Oak Ridge National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that there is an excellent approach on understanding the influence of elemental segregation on delaying coarsening of the theta prime precipitate and on using Al-nickel (Ni) alloys as the base material.

Reviewer 2:

This reviewer indicated that the project team utilizes various state-of-the-art characterization tools to reveal microstructure details of the aluminum (Al)-copper (Cu)-magnesium (Mg)-zircon (Zr) (ACMZ) alloy. The selection of techniques shows the project team knows how to effectively utilize resources provided and supported by DOE to advance the project. The reviewer found that each experiment was well designed to address the scientific issues relevant to the project tasks.

Reviewer 3:

The reviewer asserted that most combustion engineers work within the constraints of materials properties currently being used in internal combustion engines (ICEs). This leaves an opportunity to find more efficient combustion recipes outside the envelope normally explored by the current modeling processes. This has led to increases in efficiency utilizing higher combustion temperatures and pressures, which help further opportunities like downspeeding. Tying this to fundamental material properties and then realizing the increases of the ability or the combustion components is exciting.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This is great work and well executed. The abilities shown are relevant and significant and will increase engine efficiency. The reviewer applauded the well-reported, great accomplishments.

Reviewer 2:

The reviewer called the microscopy work on interfacial solute segregation impressive. It highlights the role of minor additions (e.g., Zr) on improving thermal stability by pinning the boundary of precipitates. The evolution of the volume fraction of various precipitates and phases as a function of annealing time was nicely characterized by synchrotron X-ray diffraction (XRD). This work takes advantages of the penetration power of high-energy synchrotron X-rays to accurately measure the volume fraction of different phases by probing the entire bulk specimen.

Reviewer 3:

According to the reviewer, these are excellent experiments demonstrating elemental segregation that contributes to elevated temperature properties by delaying coarsening of theta prime precipitates. The silicon mechanism was not clear to the reviewer. Integrated computational materials engineering (ICME) appears general to all similar projects. Application to the specifics of MAT217 was not clear.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that the project team has close collaboration with several DOE labs and a university to take advantage of the strength of each unique contributor to accomplish the tasks.

Reviewer 2:

There is good collaboration between the various national laboratories and industry, according to the reviewer.

Reviewer 3:

The reviewer noted that the presentation explained the partnerships between industry and national laboratories participating in this work.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

This is well thought out, and the reviewer believed that the work on the thermal and electrical conductivity-microstructure relationships co-optimized with mechanical properties could be significant in the EV arena as well as for ICEs.

Reviewer 2:

According to the reviewer, the project team nicely showed that interface boundary pinning by minor elements (e.g., Zr) is key to improving thermal stability. It is good to see the project team continuing to pursue this direction.

The project team mentioned a plan to “Employing new alloy design strategies to increase the temperature limit of Al alloys.” The reviewer said that it would be nice if the project team can elaborate more on this point.

Reviewer 3:

It was not clear to the reviewer how neutron diffraction will apply to designing microstructures. Optimizing thermal and electrical conductivity with mechanical properties is a whole different undertaking, and the approach for this was unclear. What new strategies to increase temperature limits are being comprehended? This reviewer suggested to be specific on how lightweight brakes will exploit this alloy and how composites fit, unless the Al-Ni alloy is the matrix.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

This reviewer asserted that development and improvement of lightweight alloys are critical for achieving DOE's goal of moving toward all EVs. Weight reduction of the vehicle will play a key part in improving range per kwh of EVs. For that perspective, the reviewer stated that R&D topics related to lightweight structural alloys will always be the focus for the years to come.

Reviewer 2:

The reviewer observed great work and further noted that this creates a platform for many opportunities to increase overall vehicle efficiency, lowering environmental impact.

Reviewer 3:

The reviewer indicated that improving elevated temperature and fatigue properties of aluminum is a good goal.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, the project team distributed the resources efficiently, and the tasks were accomplished in a timely manner.

Reviewer 2:

The reviewer observed that this is a well-managed project with clear goals, accomplishments, and data.

Reviewer 3:

The reviewer stated that the resources are sufficient for this difficult goal.

Presentation Number: mat218
Presentation Title: Selective Material Processing to Improve Local Properties (2B2)
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

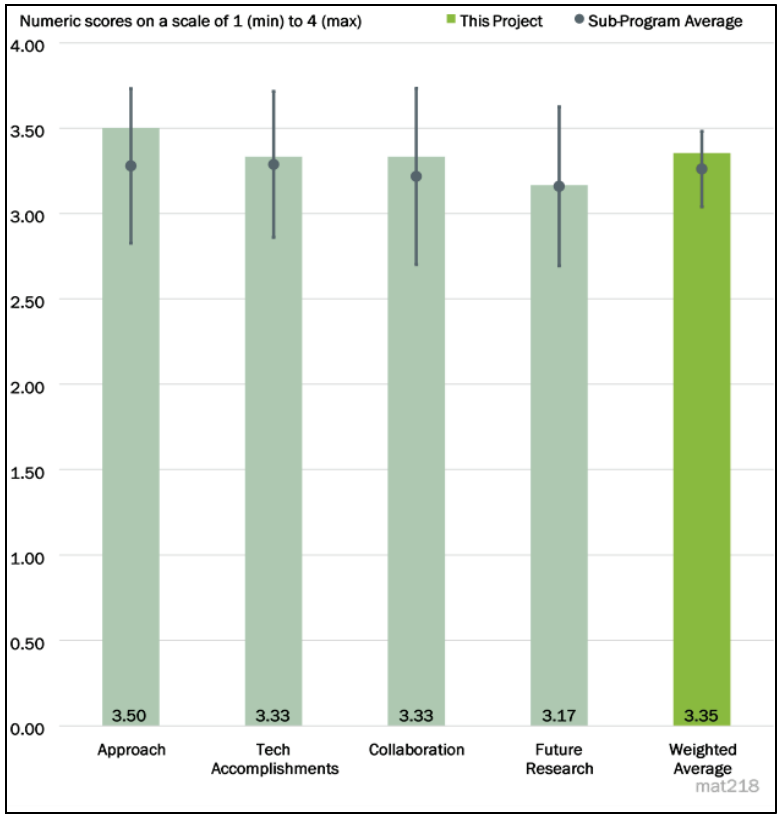

Figure 6-45 - Presentation Number: mat218 Presentation Title: Selective Material Processing to Improve Local Properties (2B2) Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that the work is based on a relatively long research history of using friction-stir processing (FSP) to heal defects and to achieve grain refinement for improved performance. This project focuses on extending that work to a complex component. Work to initially validate the approach and define key challenges (robotic friction-stir welding [FSW] systems and path planning) is prudent and represents a well-thought-out approach.

Reviewer 2:

This is a novel approach to improving material properties, but the reviewer asked what the cycle times are for the process and whether FSW would be feasible in a production environment.

Reviewer 3:

This reviewer observed a comprehensive and reasonable list of challenges and barriers that was identified for current and future tasks. For Task 2B2, the Pacific Northwest National Laboratory (PNNL) team focused on put the right property in the right place, instead of putting the right material in the right place. This work developed an effective way of introducing cast-in holes at the desired locations to demonstrate the effectiveness of FSP, one of the proposed approaches for local property improvement, on porosity elimination.

The reviewer explained that it leads to improvement of fatigue properties of cast plates at low temperature. For high-temperature properties, especially fatigue life, the team proposed a novel hybrid-processing method, i.e., cold spray followed by FSP, to achieve local up-alloying. However, the reviewer suggested that it would be beneficial if the team could establish a quantifiable correlation between pore size and FSP tool geometry, i.e., what would be the upper limit of porosity elimination as a function of tool size. Furthermore, it was mentioned in the Remaining Challenges and Barriers that FSP creates a microstructure gradient (especially a softened heat-affected zone) and therefore a property gradient in high-strength materials. However, it was unclear to the reviewer whether the team will have potential solutions—how to optimize the gradient for property control—or it would remain as a challenge for application of this technique at the end of the project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The demonstration of basic processing and development of programming for the complex component are good. The reviewer suggested that some focus should be given to the constraint issues associated with complex Al castings.

Reviewer 2:

The reviewer found the results interesting results, but it would have been useful to the reviewer for the team to have differentiated what is new and novel from the project versus what is already known in industry about FSW.

Reviewer 3:

The PNNL team is making effective progress toward subtask 1a and 1b. As previously mentioned, the reviewer remarked that the accomplishments could be improved further if a quantifiable correlation between pore size and FSP tool geometry can be established, which serves as guidance for practical application of the processing technology.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that this project team has an excellent combination of two national laboratories, one company, and one university.

Reviewer 2:

This project appears largely to be a collaboration between PNNL and General Motors (GM). GM of course brings the product focus into the project. The reviewer suggested that the project would of course benefit from a greater number of automotive partners.

Reviewer 3:

The reviewer said that it is very good to have an OEM involved to have a direct impact on industry.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

This reviewer remarked that the forward look is excellent. The reviewer expressed interest in seeing more focus on the challenges of FSP of complex castings. This would involve thermal and mechanical analyses, tooling developments, and design guidelines that would make products more amenable to the technology.

Reviewer 2:

The pathway from test coupons to real engine-part testing was not clear to the reviewer.

Reviewer 3:

The reviewer stated that the PNNL team has a reasonable plan moving forward for the majority of the challenges identified. However, it was pointed out that FSP creates a microstructure gradient (especially a softened heat-affected zone) and, therefore, a property gradient in high-strength materials. It was unclear to the reviewer what the research plan is for this challenge, whether there are alternate pathways, and what the appropriate decision point would be. Also, it is unclear whether the team will evaluate the additive FSP as mentioned in the Approach.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The technical target of this effort is to identify a suite of low-cost, advanced manufacturing processes that can improve the local properties of castings and allow higher performance. According to the reviewer, this project has well demonstrated the components having locally improved low-temperature mechanical properties and with no casting defects.

Reviewer 2:

Next-generation ICEs are a key component in the near-term energy-efficient transportation strategy. The reviewer remarked that this work clearly will play a role in enabling more compact and efficient ICE designs.

Reviewer 3:

The reviewer noted that improved material properties can help save engine weight, which will help reduce fuel consumption.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that the team has all the required resources in its possession, partly from the existing capability and partly from the assistance of the collaborating company, for the project to achieve the stated milestones in a timely fashion.

Reviewer 2:

The reviewer said that the project is on track.

Reviewer 3:

The reviewer would have liked to see more direct focus on the metallurgy of strontium (Sr)-stabilized Al castings.

Presentation Number: mat219
Presentation Title: Fundamentals of Non-Equilibrium Processing
Principal Investigator: Ying Yang (Oak Ridge National Laboratory)

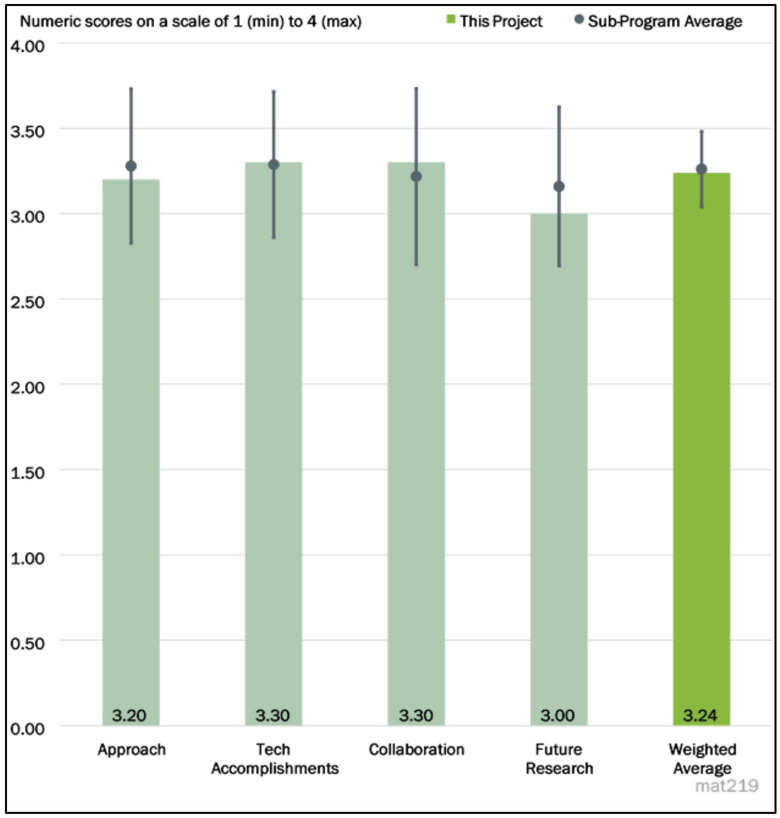

Figure 6-46 - Presentation Number: mat219 Presentation Title: Fundamentals of Non-Equilibrium Processing Principal Investigator: Ying Yang (Oak Ridge National Laboratory)

Presenter

Ying Yang, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

According to the reviewer, the PI’s approach toward the non-equilibrium AM processing is good. The presenter describes the Al-cerium (Ce)-manganese (Mn) investigation as both theoretical microstructural modeling and experimental. The project team has developed a thermodynamic database for Al-Ce-Cu system. The PI understands that the need to understand the discrepancy between calculated and experimental results.

Reviewer 2:

The reviewer said that it is a well-designed and well-planned project, and the technical barriers are addressed.

Reviewer 3:

The reviewer commented that this project is good in the sense that it will help to understand the material behavior during the AM process. Early results show that the AM alloys can show higher strength and ductility compared to the conventionally cast alloys. However, the reviewer stated that the goal is not specific enough. Maybe generating a phase diagram for an AM alloy would be a reasonable goal to achieve. Additionally, the reviewer noted that there is slight confusion in terms of progress and schedule. It shows that the project will start in October 2021, and yet it already achieved 50% of the goal.

Reviewer 4:

The reviewer remarked that this work addressed the challenge that phases observed in some Al alloys solidified at fast cooling rates associated with AM processes are not predicted using the conventional thermodynamic database. The ORNL team developed new databases using a combination of CALculation of PHAse Diagram (CALPHAD), first-principle calculations, and experimental verification through advanced characterization tools, which takes into consideration of solute trapping nucleation kinetics and growth kinetics. Reasonable agreement between the solidification model and experimental observation was achieved in AM of austenitic stainless steels and the Al-Ce-Ni-Mn system. A discrepancy was observed in the Al-Ce-Cu system, and the project team is planning to evaluate the kinetics effect; however, the researchers did not clarify how the kinetics term would be introduced in the AM microstructure with inhomogeneous composition distribution. The investigation of a diffraction profile in progress is expected to provide more in-depth understanding of the actual phase evolution.

Reviewer 5:

This reviewer noted that the approach starts with development of thermodynamic databases that would be used for populating the solidification models. The reviewer commented that this approach addresses, and attempts to improve on, the limited knowledge of microstructural evolution for materials fabricated from non-equilibrium conditions. The approach does not discuss limited phase diagram data as applied to new alloys fabricated by rapid solidification. The Background slides discuss phase diagram data and the problems with databases that are not sufficient to predict accurate phase diagrams, but this is not addressed on the Approach slide or discussed as part of the project approach. The rest of the presentation discusses solidification modeling. This could be an oversight by the presenter to focus on just one of the barriers. Maybe the phase diagram problem was solved in the first year of the project, but this is not indicated in the presentation.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer remarked that the team has developed a solidification model for understanding the as-printed microstructure of austenitic steels and produced one journal paper. In addition, the team has developed thermodynamic and kinetic models for understanding the as-cast microstructure of the Al ternary system from AM and submitted one manuscript.

Reviewer 2:

The project identified an important issue for characterizing material properties due to AM process and provides a design capability to improve material characteristics. According to the reviewer, the thermodynamic database of Al-Ce-Ni-Mn will be useful for future modeling and simulation. It just needs to be calibrated and validated for its accuracy.

Reviewer 3:

The PI and the project team developed a thermodynamic and kinetic model for understanding the as-cast microstructure of the Al-rich Al-Ce-Ni-Mn system ($Al_{11}Ce_3$, $Al_{10}Mn_2Ce$, $Al_{20}Mn_2Ce$, and $Al_{23}Ni_6Ce_4$) and M (M=Cu, Ni) ternary system from AM. The PI said that AM alloys show both increased strength and ductility compared to conventionally cast alloys, but the reviewer commented that this is not always true for testing the AM from within the plane of laser to the different layers on top of the plane.

Reviewer 4:

Reasonable agreement between the non-equilibrium solidification models and advanced experimental characterizations (e.g., atom probe tomography [APT]) has been demonstrated in AM austenitic stainless steels and the Al-Ce-Ni-Mn system. It would have been beneficial to the reviewer for the team to have clarified whether the continuous cooling transformation (CCT) diagrams will be updated for the alloy systems of interest, since the solidification rate may vary significantly across different AM processes.

Reviewer 5:

There was no project schedule or any performance indicators discussed in the presentation; so, it was difficult for the reviewer to determine the degree that progress has been made. The Milestone slide only gives two milestones for FY 2021 and states that one was completed, and the other is on track. The reviewer had to assume that there were more than two milestones for this project and there must have been performance indicators for regular and specific, measurable, attainable, relevant, and time-bound (SMART) milestones and go/no-go decisions that were achieved.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer noted that close collaboration has been demonstrated between the ORNL and the University of Tennessee-Knoxville (UTK) teams through successful completion of subtask 3A1. Good coordination has been demonstrated between ORNL and ANL team for the ongoing task of diffraction measurement in the Al-Ce-Ni-Mn system.

Reviewer 2:

The reviewer said that the ORNL team leads the tasks in partnering with UTK.

Reviewer 3:

The PI has assembled a good collaboration between the different national laboratories (ORNL and ANL) with some collaboration with academia (UTK); the reviewer suggested that this project could benefit from some industry involvement. For example, Eck Industries has completed a lot of work on cast Al-Ce-Cu systems.

Reviewer 4:

Collaboration is mentioned within the thrust areas. The reviewer stated that it would have been better to collaborate with academia and industry as well.

Reviewer 5:

The reviewer found the collaboration to be limited between ORNL, ANL, and UTK. The coordination between tasks for Thrust 3 appears to be good, but there was only one indication that ANL contributed to the task by investigating crystal structure at their Advanced Photon Source. There is no indication of external collaboration and who will benefit from the results of this project.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer encouraged the project team to include a task to make 100% densification (no porosity) with avoiding a post process such as hot isostatic pressing (HIP). The tasks of complete development of thermodynamic databases and understanding phase formation and evolution in Al-Ce-Ni-Mn and Al-Ce-Cu alloys are well planned.

Reviewer 2:

The PI and the project team are going to work on incorporating additional factors into the existing microstructural models for non-equilibrium conditions due to rapid solidification during AM.

According to the reviewer, modeling Ce's electron valance shell is extremely complicated and needs further attention to the two electrons in its outermost ($6s^2$) shell. The valance shell behaves as though it has three or four valence electrons (the $5d^1$ and $4f^1$ electrons may also participate). This could be why the PI said that the thermodynamic databases are often not available or are not reliable for Al-Ce-X (X=Mn, Cu, Ni) systems.

Reviewer 3:

The reviewer said that most future research topics are the continuation of the current work.

Reviewer 4:

The updated and verified thermodynamic database will be incorporated into the existing microstructure models for more accurate prediction of microstructure evolution during AM processes with far-from-equilibrium solidification rates. However, the reviewer commented that there is insufficient information provided for the key barriers related to introducing additional factors into the solidification model.

Reviewer 5:

The reviewer indicated that the proposed future research is simply completing the existing tasks and then continuing the same database development and microstructural modeling if further funding is provided beyond FY 2022. Nothing is stated about what information or technology will be transferred that may require additional research or how much more is needed for database and model development. There are no timeframes for deliverables, which indicates there are no deliverables, just data generation.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer reported that development of robust alloys for AM continues to be a large portion of materials R&D efforts around the globe.

Reviewer 2:

The reviewer said that the scope of work is well aligned with the overall DOE objectives.

Reviewer 3:

The reviewer remarked that characterizing AM material properties is closely related to DOE objectives.

Reviewer 4:

According to the reviewer, this project addresses the challenges related to limited phase diagram data and their applicability for AM of existing and new alloys due to far-from-equilibrium solidification.

Reviewer 5:

This project supports an overall DOE objective to address AM of advanced materials. The reviewer found no direct reference cited although the Workshop Report on Trucks and Heavy-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials states that there are insufficient computational modeling tools for materials development, manufacturing, processing, and assembly currently in place that focus on advanced powertrain materials.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that it takes a lot of resources to involve microstructural modeling with experimental validation, and the PI has good resources. However, again the PI might want to talk to industrial resources (i.e., Dave Weiss at Eck Industries) regarding the cast Al-Ce-Mn series.

Reviewer 2:

The reviewer noted that the team has sufficient resources to carry out the planned tasks.

Reviewer 3:

It seemed to the reviewer that the project has sufficient resources to perform the proposed tasks.

Reviewer 4:

According to the reviewer, the researchers have sufficient resources at ORNL and partner sites to achieve the stated milestones in a timely fashion.

Reviewer 5:

The funding shown is $140,000 for FY 2021 and a start date of October 2021, which has not occurred yet. The Overview slide shows zero funding previously although there is one slide that states, "New databases were developed that can predict the correct phase diagrams." The reviewer understood that the project was funded $140,000 in FY 2021 and that this has to last through the end of the project in September 2023 (FY 2022) since no FY 2022 funding is identified. With the project 50% complete in June 2021, $70,000 must have been spent in FY 2021 and $70,000 will be spent in FY 2022, which are adequate and sufficient for the database and modeling efforts described.

Presentation Number: mat220
Presentation Title: Ferritic Alloys for Heavy-Duty Pistons via Additive Manufacturing (3B2)
Principal Investigator: Peeyush Nandwana (Oak Ridge National Laboratory)

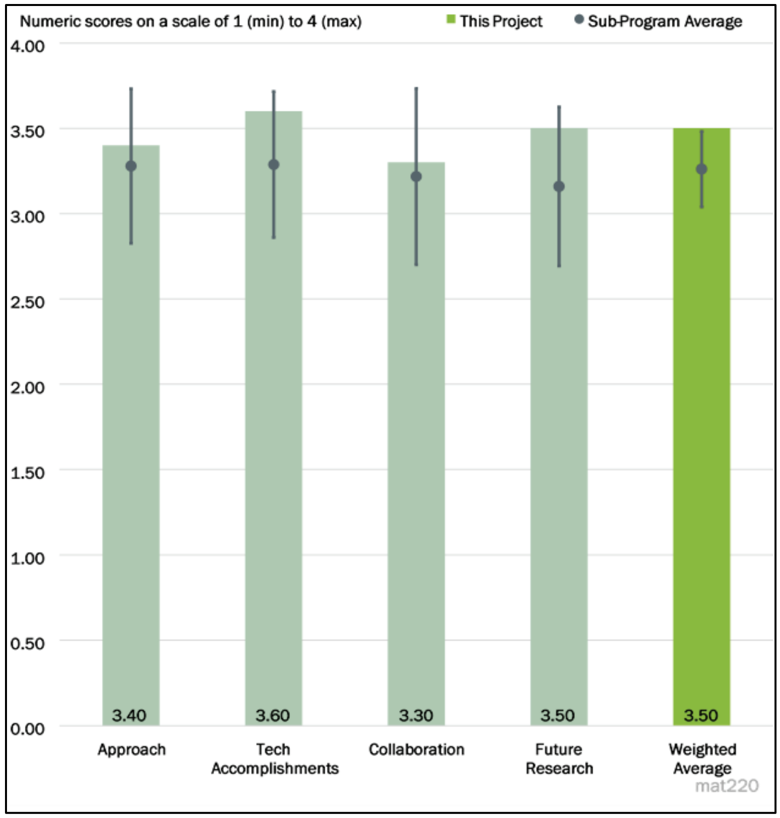

Figure 6-47 - Presentation Number: mat220 Presentation Title: Ferritic Alloys for Heavy-Duty Pistons via Additive Manufacturing (3B2) Principal Investigator: Peeyush Nandwana (Oak Ridge National Laboratory)

Presenter

Peeyush Nandwana, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach is focused on one alloy system (H13) and its use in conjunction with binder-jet printing for producing materials for piston applications. The choice of this material as a focus is based on opportunities for improved oxidation resistance and potential for improved strength, relative to other steels used for this application. The approach integrates fabrication, characterization, and ICME modeling to optimize heat treatment. This approach was reasonable to the reviewer, although challenges associated with the predictive capabilities of the ICME models were described.

Reviewer 2:

The reviewer remarked that the project approach is to use binder-jet AM process to demonstrate fabrication of an engine component using a commercial alloy H13. The project involves ICME modeling, binder-jet printing, part densification, and characterizations. Challenges with binder-jet printing are related to distortion and dimensional changes post-densification, which the team has addressed by experimentation. Other challenges, such as microstructure evolution and process controls, are being addressed using modeling and experimental validations.

Reviewer 3:

The project uses the binder-jet process to produce a steel cylinder with densification and minimum shape change. It turned out that the manufactured material shows higher strength at low temperature (less than 500°C) but quickly deteriorates at high temperature. But, overall, the ultimate tensile strength (UTS) is higher than 4140. However, it was unclear to the reviewer if the final shape is good enough to be used as a cylinder because the part requires really tight geometric tolerances and surface smoothness. Eventually, the part may still need machining to be used in practice. The project started in 2018 and is ending in 2022, and yet, the 50% progress seems too slow.

Reviewer 4:

The approach is a typical generic linear process for material development going through the steps from material fabrication to materials characterization including some modeling for process optimization. There was nothing in the presentation that discussed the degree to which the technical barriers are now being addressed or will be addressed. The reviewer found nothing special about the approach, which has been previously demonstrated to be very feasible.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The accomplishments include fabrication of binder-jet printed H13 samples with improved strength relative to 4140 and micro-alloyed steel (MAS), improved oxidation resistance relative to 4140, microstructural characterization of carbides that informs the need for homogenization and optimized heat treatments, and CALPHAD modeling of microstructure evolution that explains the origin of the impacts on strength associated with thermal history. Overall, the project has demonstrated good progress toward its technical goals.

Reviewer 2:

Results for the material characterization of carbide morphologies were excellent. Results for strength were good but did not demonstrate that the binder-jet H13 alloy was as good as conventional H13, only better than commercial steel alloys. Modeling results for the microstructure analysis and strength showed good results for comparing the as-sintered H13 to H13 up to 800°C. The results of the neutron diffraction studies were good for comparing the phase evolution of the as-sintered versus the sintered plus HIP plus high-temperature (HT) condition. HT cyclic oxidation results showed a two-fold reduction in oxidation for the binder-jet H13, which is much improved performance. Simulation results were excellent for the effect of packing density on part shrinkage. Overall, the technical accomplishments were outstanding for the amount of resources available.

Reviewer 3:

The project target to exceed the yield strength (YS) of 4140 and MAS steels might be achieved. It would be necessary to compare the manufacturing cost as well. Further investigation would be required to understand the rapid drop of strength over 500°C.

Reviewer 4:

Excellent technical progress has been made in the project. The project team has demonstrated fabrication of H13 alloy parts using the AM approach and performed characterizations to show that final mechanical properties of the material is superior to 4140 and MAS and similar to the conventional H13. However, the reviewer suggested that there are few items that need to be addressed, including the following: what the acceptable dimensional variabilities are on the component being targeted and how they compare with the part produced using the binder-jet processing approach; if there are any American Society for Testing and Materials (ASTM) standards that need to be adhered to; if there are any limitations on the size of the part targeted based on de-binding and densification steps; and if there is process repeatability from run to run.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This project involves collaboration between ORNL and PNNL and partnerships with Zeiss and (starting this fiscal year) the Army Ground Vehicle Systems Center (GVSC). The reviewer mentioned that the collaborations and partnerships bring together a blend of complementary capabilities and appear to be effectively coordinated.

Reviewer 2:

The project is well coordinated with the Powertrain Materials Core Program (PMCP) program and the various teams at ORNL and PNNL. The reviewer suggested that it may be good to have some interaction with an OEM or component manufacturer to understand the challenges and requirements for the part manufactured at scale.

Reviewer 3:

The reviewer found a good collaboration within ORNL. It would be better to have collaboration with academia and industry.

Reviewer 4:

The reviewer indicated that the collaboration and coordination are mostly internal at ORNL between resources at the Spallation Neutron Source (SNS), the Center for Nanophase Materials Sciences (CNMS), and the Manufacturing Demonstration Facility (MDF). PNNL is only providing APT and transmission electron microscopy (TEM) for analysis. The collaboration with Zeiss is not stated. There is a statement regarding current and future collaboration with the Army's GVSC, but nothing is stated as to the extent of the collaboration.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

A number of remaining challenges and barriers are identified, spanning understanding of the impact of long-term thermal exposure on materials properties, the mechanism of superior oxidation performance, improving the relevant ICME models, and establishing thermal properties. Creep and fatigue resistance testing was not mentioned in this context, but the reviewer anticipates that this will be important for establishing suitability of these materials for piston applications.

Reviewer 2:

The key challenge for the technology is the dimensional control and repeatability. The team has identified these challenges as well; however, the reviewer stated that a plan needs to be laid out as to how this will be addressed.

Reviewer 3:

The reviewer said that the future research proposes evaluating long-term thermal exposure, which also goes with the proposed work to evaluate thermal properties for piston applications. This will be needed for acceptance of the alloy by parts manufacturers. Predictive modeling using an ICME approach would be a good addition to this research. Design of new heat treatments using an ICME approach or modifications to the alloy chemistry will also be very beneficial to this new alloy development.

Reviewer 4:

The reviewer commented that it would be better if future research focuses on understanding the material property changes on temperature.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer noted that the project supports the development of binder-jet AM as a solution for achieving improved efficiency of heavy-duty engines and as a means for low-cost tooling for automotive applications. These goals are consistent with DOE objectives in Thrust 3 on AM for Advanced Powertrains.

Reviewer 2:

According to the reviewer, this project directly supports the overall DOE VTO technical targets for materials development and the U.S. DRIVE roadmap strategy for advanced material development of high-performance materials used at elevated temperatures in automotive powertrains fabricated with advanced manufacturing process methods.

Reviewer 3:

The reviewer indicated that this project supports cost-effective manufacturing of vehicle engine components that will improve system efficiencies and minimize fuel consumption.

Reviewer 4:

The reviewer said that the project is closely related to the overall DOE objectives.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer asserted that the funding is about $200,000 per year, which is sufficient for the material development and the characterization and analysis of the new alloy compositions fabricated by AM. The number of researchers and collaborators is adequate for each technical area being addressed.

Reviewer 2:

The resources appeared to the reviewer to be sufficient to enable the progress demonstrated, and the project appears to be on track.

Reviewer 3:

It seemed to the reviewer that the project has enough resources to perform all the tasks.

Reviewer 4:

The reviewer indicated that the project has sufficient resources for timely completion.

Presentation Number: mat221
Presentation Title: Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials
Principal Investigator: Dean Pierce (Oak Ridge National Laboratory/Cummins)

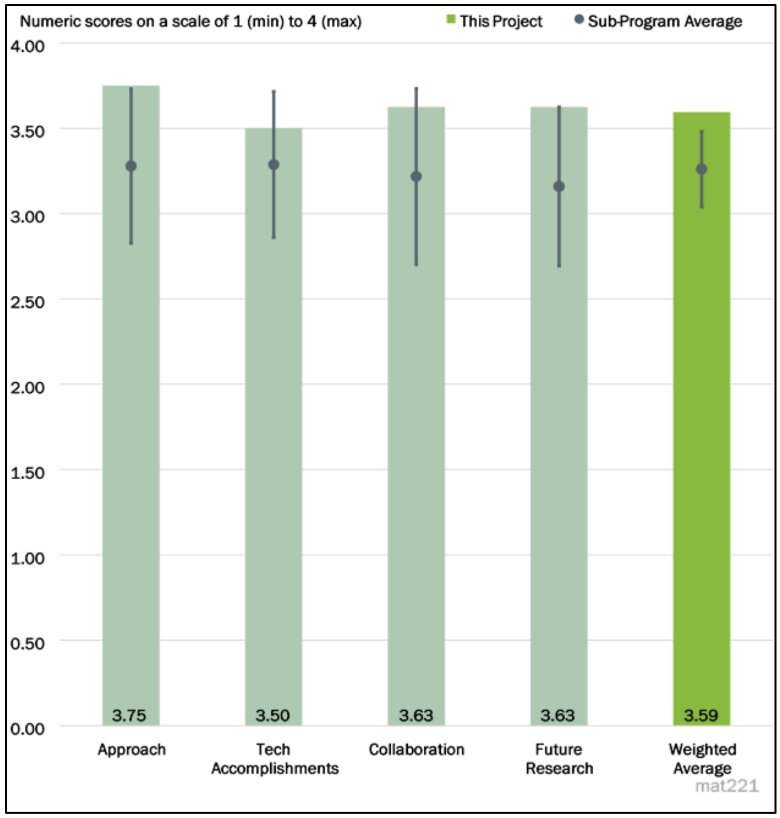

Figure 6-48 - Presentation Number: mat221 Presentation Title: Lightweight and Highly-Efficient Engines Through Al and Si Alloying of Martensitic Materials Principal Investigator: Dean Pierce (Oak Ridge National Laboratory/Cummins)

Presenter

Dean Pierce, Oak Ridge National Laboratory/Cummins

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that the work addresses a key technical barrier associated with the limits of currently used steels in the context of improving efficiency and downsizing and lightweighting of engines. This challenge has been addressed over the past year through an alloy design strategy that integrates computational modeling, lab-scale fabrication, and property testing. The emphasis has been on identifying alloys with combinations of oxidation resistance, strength, and fatigue resistance that enable applications for pistons operating at higher temperature (600°C) and pressure. Work is underway to scale up and to manufacture pistons for engine testing and design.

Reviewer 2:

Since it is an industry-led project, the reviewer noted that some of the details were not disclosed. Nevertheless, it is a well-planned and, so far, well-executed project. The focus is to develop novel alloys that perform at temperatures greater than 500°C for possible replacement of 4140 steel and MAS used for piston applications. The project utilizes computationally designed alloy compositions, lab-scale fabrication, and evaluation of thermo-mechanical properties. Successful alloy composition will be used for prototype fabrication for engine testing.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer said that good progress was demonstrated. Although the details were not authorized for public release, the successful development of a cost-effective steel with improved strength, oxidation resistance, and good fatigue properties was demonstrated at lab scale. The results show promise for applications at temperatures significantly higher than the existing 4140 steels that are limited to peak temperatures of 500°C.

Reviewer 2:

According to the reviewer, the project has progressed very well. Various alloy compositions have been fabricated and properties characterized. The new alloy has demonstrated superior strength, fatigue, and oxidation resistance at temperatures greater than 500°C as compared to the currently used 4140 steel and MAS. Based on the properties of the new alloy, using modeling the potential of increased engine efficiency has been demonstrated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that this work is being performed under a cooperative research and development agreement (CRADA) in close collaboration and coordination with Cummins, who is investing significant cost share.

Reviewer 2:

It was difficult for the reviewer to assess which task has been done by which partner. In any case, it appears that the collaboration of project partners Cummins and ORNL is excellent. In addition, it is nice to see that a project has involved a manufacturer of piston parts.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

It was not clear to the reviewer if one or more than one alloy composition is the target of the scale-up activities for the next year. These activities will address bottlenecks associated with manufacturing of pistons, and it would be interesting to understand whether pursuit of a few different alloys in parallel may be desirable in case unanticipated barriers are encountered in these scale-up and testing efforts.

Reviewer 2:

According to the reviewer, the project next steps are in accordance with the overall goal of the project. The team will perform scale-up of alloy fabrication to ensure that the properties are maintained. Following that, piston prototypes will be manufactured and tested in an engine to validate their performance. The team has indicated several manufacturing processes to make the piston. It may be better to downselect one or two manufacturing processes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the work is supportive of the DOE objectives by targeting a strategy for downsizing and lightweighting of engines for heavy-duty, long-haul freight.

Reviewer 2:

The reviewer commented that the project addresses development of new alloys for engine applications so that the engines can operate at higher temperatures reliably, leading to higher fuel efficiencies and lower environmental impact.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The work seemed to the reviewer to have sufficient resources to support the modeling, fabrication, and property testing of candidate alloys. There was no evidence of resources placing limitations on the progress of the work.

Reviewer 2:

The reviewer remarked that the resources are adequate and readily available at both the partners for timely completion of the project.

Presentation Number: mat222
Presentation Title: Extending Ultrasonic Welding Techniques to New Material Pairs
Principal Investigator: Jian Chen (Oak Ridge National Laboratory)

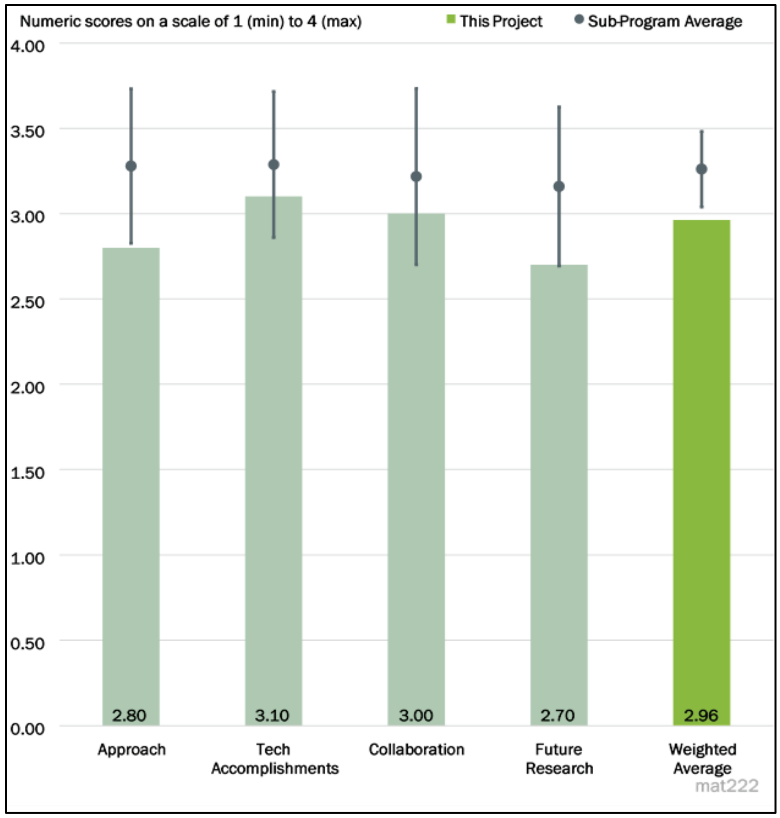

Figure 6-49 - Presentation Number: mat222 Presentation Title: Extending Ultrasonic Welding Techniques to New Material Pairs Principal Investigator: Jian Chen (Oak Ridge National Laboratory)

Presenter

Jian Chen, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The diagram on Slide 4 is quite clear. Process development and the effect on weld properties are clear along with imaging techniques being applied in situ. However, the reviewer suggested that it would be value added to consider how one would be able to capture the effects of modal interaction in situ.

Reviewer 2:

The approach is very clear and complete and looks competent. What was not clear to the reviewer is that what this project will add to the rather extensive understanding the community has of ultrasonic welding. Many materials pairs, thicknesses, and process variants have been used. It is not fully clear how this investment will produce truly new fundamental or applied knowledge. This may be mostly an issue of communicating the value.

Reviewer 3:

It is the first year of the project. There are not many details in the proposed technical approaches. It was not very clear to the reviewer what the differences are between this project and the Phase I project. It seems the material combinations and coupon geometry and size will be different.

Reviewer 4:

According to the reviewer, a clear objective was not provided, and the future work did not explain what type of characterization of the joints was to be conducted. Corrosion was not part of the picture, and this creates concerns when steel or iron (Fe) is to be joined to Mg. The plan should have involved the use of a barrier, and this was not discussed either.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Because the project just started in December, the reviewer remarked that the project has made appropriate progress in setting up the key variables and approaches.

Reviewer 2:

This project is in its early stages but appeared to the reviewer to be making clear progress with experiments and analysis underway.

Reviewer 3:

The reviewer indicated that the team has established the material set, welding schedule, and instrumentation for initial welding trials, temperature measurement, and initial numerical simulations.

Reviewer 4:

This is a relatively new project, and the reviewer remarked that progress to date is good.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer stated that the team consists of three national laboratories and fully utilized the expertise of each laboratory, such as expertise on welding from ORNL, advanced electron microscopes from PNNL, and X-ray synchrotron from ANL.

Reviewer 2:

The burden is on ORNL, and the funding distribution clearly supports that. However, it was not clear to the reviewer how the X-ray synchrotron source is to be used in this project.

Reviewer 3:

The project seemed to the reviewer to be a well-planned collaboration between national laboratory experts. It may be useful to engage universities, industry, and students to maximize dissemination of knowledge.

Reviewer 4:

The reviewer acknowledged that the tasks are well shared, but the nature of the collaboration (meetings, their frequency, and relevant feedback from the collaborators) is not given.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The project has projected a logical progression to additional lightweight material pairs based upon initial success of steel-Mg joints. The reviewer strongly suggests prioritizing modal analysis modeling over the thermo-mechanical modeling. The internal work in ultrasonic spot welding (USW) of CFRP highlighted the strong impact of adjacent welds depending upon spacing on the heat generation. The reviewer assumed that that this would be no different in metals.

Reviewer 2:

The plan is clear. As stated before, it was not fully clear to the reviewer what is truly new to be provided by this project.

Reviewer 3:

It seems that for every material combination with the proposed methods, new research using USW has to be conducted, which is very time consuming. The reviewer suggested formulating a general trend or method to accelerate the development of USW with different material combinations.

Reviewer 4:

The reviewer found that the future work is rather sketchy, but perhaps this is due to the start date being only December 2020.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, the reviewer asserted that it is imperative to achieve dissimilar material joints. In order to implement such dissimilar material joints, the knowledge of process parameters and their effect upon mechanical performance is necessary.

Reviewer 2:

The reviewer indicted that multi-material joining is essential to lightweighting and therefore minimizing energy use in transportation.

Reviewer 3:

According to the reviewer, joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency.

Reviewer 4:

The reviewer opined that joining of dissimilar materials is very important in vehicle lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer observed a very well-funded project.

Reviewer 2:

According to the reviewer, the national laboratories have enough resources to fulfill the research goals on time.

Reviewer 3:

The reviewer stated, however, that it is a little difficult to assess because the future work plan is not well detailed.

Reviewer 4:

A listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project. Also, as noted previously, Argonne's contribution was not clear to the reviewer.

Presentation Number: mat223
Presentation Title: Extending High Rate Riveting to New Material Pairs
Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

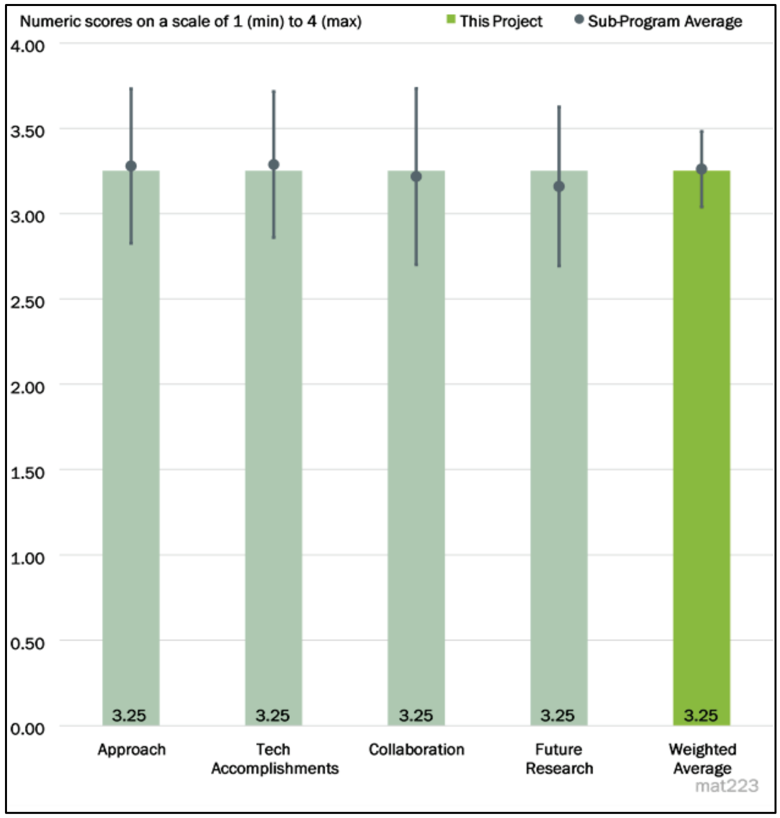

Figure 6-50 - Presentation Number: mat223 Presentation Title: Extending High Rate Riveting to New Material Pairs Principal Investigator: Kevin Simmons (Pacific Northwest National Laboratory)

Presenter

Kevin Simmons, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer asserted that the technical approach is very comprehensive, from an experimental and modeling study of the joining processes to joint structure, performance, and end of life recycling.

Reviewer 2:

According to the reviewer, the project is well explained, and the goals are clear with the exception that how the model will be validated is not mentioned anywhere.

Reviewer 3:

This project studies two interesting and innovative processes. They are interesting and can have important impacts. It seemed prudent to the reviewer to really understand the process before developing it. Some more basic work on mechanisms, of the high velocity "riveting" in particular, needs to be performed. It seems that the basic mechanism of joining is not understood.

Reviewer 4:

Although some work has been completed regarding adhesives, none of the remaining three milestones mentions hybrid solid state/adhesive joining, and no go/no-go milestones were called out for the 3-year project. However, reading through the future work indicated to the reviewer that the approach is well thought out.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Although this project is in its very early stages, it seemed to the reviewer that progress is going well with technical work underway.

Reviewer 2:

The reviewer reported that the team has accomplished milestones 1 and 2 in the first year.

Reviewer 3:

Given that this is a relatively new project, the reviewer commented that some of the tasks are in progress but may be on track.

Reviewer 4:

The reviewer found it difficult to assess technical accomplishments because progress is only at 5%.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The team consists of three national laboratories and fully utilizes the expertise of each laboratory, such as expertise of high-velocity rivet (HVR) and high-rate friction rivet (HFR) processing and characterization from PNNL, curing and rheology studies from ORNL, and X-ray synchrotron from ANL.

Reviewer 2:

The reviewer noted that the collaboration map is a very good feature and well-detailed as well.

Reviewer 3:

Slide 10 provides a nice overlap of the three national laboratories, but it is a bit disconcerting that ANL is not getting any funding in 2021. It seemed to the reviewer that some initial imaging should be completed in Year 1 to at least validate feasibility of future deliverables and provide feedback to the other members of the team.

Reviewer 4:

Good collaboration, but having no industry, universities, or students seemed to the reviewer to present a fundamental barrier to really getting the technology outside the national laboratories.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

An excellent plan is being executed though it seemed to the reviewer that both fundamental joining mechanisms need to be studied. Also, equipment that can repeatedly develop 500 meters (m)/s impact is a real challenge. It seems prudent to examine the literature on dynamic forging presses. These had a lot of promise in the 1970s, but mostly fatigued themselves to death.

Reviewer 2:

In general, the proposed future research is logical, and this reviewer provided the following for the team to consider:

- Is the mechanical performance of an adhesive joint the same regardless of the path taken to achieve 100% cure?
- Adhesive is typically used for galvanic coupling so why investigate plasma pretreatment and not something like plasma coating or laser ablation, which has been shown to provide improved adhesive bond durability post environmental exposure (which plasma treatment alone does not)? It seems that would be more relevant.
- Include modeling of the hybrid joint, especially in the coupled adhesive-rivet plasticity and fracture behavior.

Reviewer 3:

The reviewer asserted that proposed future work meets the research goal very well. However, there is no task related to the end-of-life recycling that was mentioned in the research goal.

Reviewer 4:

The reviewer emphasized that model validation must be included here.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, the reviewer asserted that it is imperative to achieve dissimilar material joints. In order to implement such dissimilar material joints, the knowledge of joint performance, such as the hybrid joints proposed here, is necessary.

Reviewer 2:

The reviewer remarked that dissimilar joining is key to vehicle mass reduction and improved efficiency.

Reviewer 3:

This reviewer indicated that joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Development of high- rate joining methods is important to industries requiring high production rates.

Reviewer 4:

According to the reviewer, the project is highly relevant; multi-material design is a key ingredient of vehicle lightweighting.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the project is well resourced for the stated objectives.

Reviewer 2:

The national laboratories have enough resources to fulfill the research goals on time, according to the reviewer.

Reviewer 3:

The reviewer commented that the budget is adequate though more funding may be required in this very valuable project.

Reviewer 4:

The reviewer observed that a listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project.

Presentation Number: mat224
Presentation Title: Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness
Principal Investigator: Piyush Upahdyay (Pacific Northwest National Laboratory/Oak Ridge National Laboratory)

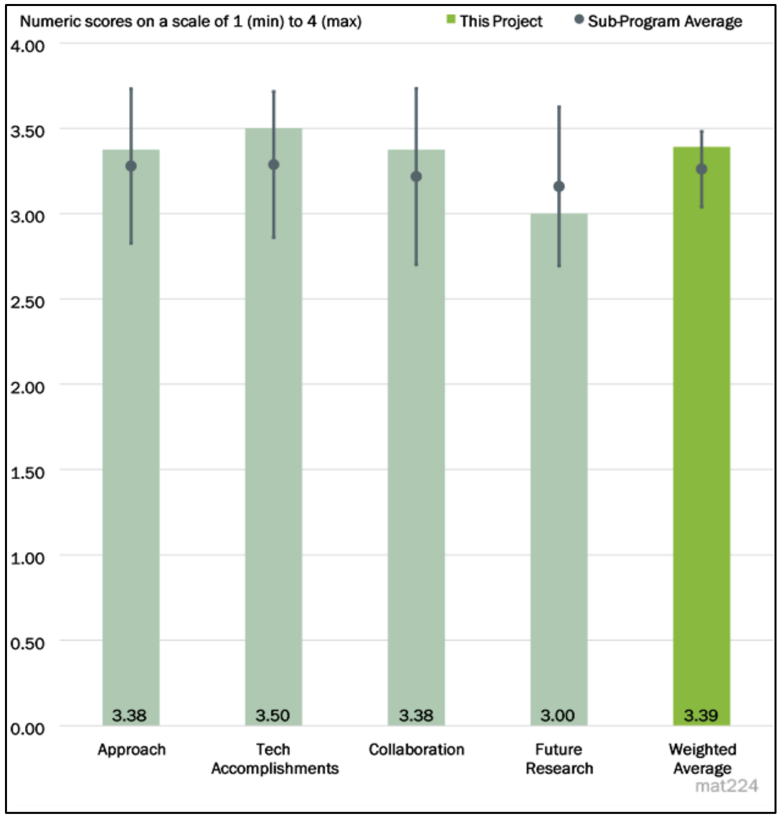

Figure 6-51 - Presentation Number: mat224 Presentation Title: Solid State Joining of Multi-Material Autobody Parts Toward Industry Readiness Principal Investigator: Piyush Upahdyay (Pacific Northwest National Laboratory/Oak Ridge National Laboratory)

Presenter

Piyush Upahdyay, Pacific Northwest National Laboratory/Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The project is extremely well laid out, and a clear direction with go/no-go targets is evident. However, the reviewer would have liked to see a statement on how the team will determine if the project is successful or not. The go/no-go targets were for Year 1 only.

Reviewer 2:

Very good work is being done by a great team. The work is not highly innovative, but it is a requirement for scaling the technology to industrial use, according to the reviewer.

Reviewer 3:

The goal of this project is to scale up the lab processes (friction-stir linear welding [FSLW] and friction self-piercing rivet [F-SPR]) to production level. The preliminary experimental work has proved the feasibility of the proposed research. If this research could identify the difference between lab scale and real production in a more general way (e.g., through simulation or machine learning [ML]), the reviewer opined that will help to accelerate the scale-up of joining processes that share similarity with these two processes.

Reviewer 4:

All aspects are explained; the reviewer said that the potential challenges related to joining to Al to CFRP are not described.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer stated that the team has made very good progress, given that the project is only 15% complete. This may be due to prior work or good organization but regardless, the reviewer called it well done.

Reviewer 2:

The program is in its early stages, but the reviewer said that research products are being developed at an impressive rate.

Reviewer 3:

Initial demonstration of the real production robotic system has been finished, which the reviewer found very impressive.

Reviewer 4:

The project is 15% completed though it is the first year and during COVID-19; the reviewer noted that other steps are on track.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that it is very good to see real industry collaboration with national laboratory resources. This bodes well for external application of the insights developed.

Reviewer 2:

The reviewer noted that this research will be performed by two national laboratories and three companies, which will strengthen the technology transfer.

Reviewer 3:

Collaboration is well explained in the presentation; the reviewer stated that there is good collaboration with the industry.

Reviewer 4:

The Responsible, Approved, Supporting, Informed, and Consulted (RASIC) management between ORNL and PNNL was not clear to the reviewer. If each lab has one joining method, then it would be critical to share joint knowledge transitioning from gantry to robotic application.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

According to the reviewer, the future work is very comprehensive and aligns well with the project objectives.

Reviewer 2:

The reviewer remarked that the plan going forward does address industry issues.

Reviewer 3:

In general, the future work is in line with the stated project targets; however, it seemed to the reviewer very limiting to only investigate corrosion of the self-piercing rivet (SPR) joints, especially with each joint having a unique path to failure.

Reviewer 4:

The reviewer suggested that more emphasis on the property evaluation of Al and CFRP joints needs to be included.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, the reviewer asserted that it is imperative to achieve dissimilar material joints. In order to implement such dissimilar material joints for industrial applications, laboratory-based technologies must be transitioned and validated in production-like environments.

Reviewer 2:

According to the reviewer, joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Transferring the technologies from lab scale to real production will realize the benefits of these technologies.

Reviewer 3:

The reviewer observed that this project is very important also for EV construction.

Reviewer 4:

The reviewer said that this work supports mass reduction.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that this project is well funded at national laboratory rates.

Reviewer 2:

The reviewer asserted that the national laboratories and industrial partners have enough resources to fulfill the research goals on time.

Reviewer 3:

The resources are well planned and sufficient, according to the reviewer.

Reviewer 4:

The reviewer observed that a listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project.

Presentation Number: mat225
Presentation Title: Surface Modifications for Improved Joining and Corrosion Resistance
Principal Investigator: Mike Brady (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

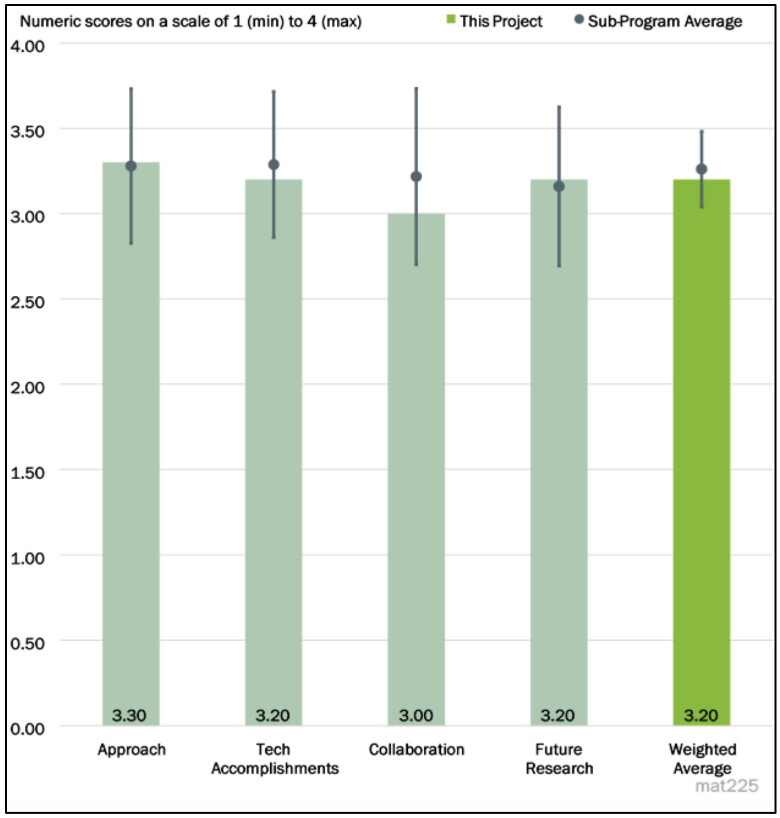

Figure 6-52 - Presentation Number: mat225 Presentation Title: Surface Modifications for Improved Joining and Corrosion Resistance Principal Investigator: Mike Brady (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

Presenter

Mike Brady, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 80% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 20% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer commented that this project provides a highly innovative method for modifying surfaces that can have important effects in mitigating corrosion.

Reviewer 2:

The reviewer remarked that the proposed approach is very comprehensive and includes processing, characterization, and numerical modeling.

Reviewer 3:

The reviewer said that the plan and objectives are well explained.

Reviewer 4:

The concept of surface modification for improved bonding following environmental exposure is spot on. However, in the slides and presentation, it was not clear to the reviewer if atmospheric plasma is limited to plasma treatment only or if this includes atmospheric plasma applied coatings. It would be interesting if the project team addressed the relative importance of surface roughness versus surface chemistry in laser ablation of the Al surface.

Reviewer 5:

The reviewer found no actual accelerated corrosion exposure of the type used by the automotive OEMs is proposed in this project.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This project is early in its development, but the reviewer said it already has impressive results.

Reviewer 2:

The reviewer stated that 10% of the work has been completed, and work seems to be on target.

Reviewer 3:

The reviewer noted that the team has accomplished milestones as proposed in the first year.

Reviewer 4:

The project has a good plan but just started so it was difficult for the reviewer to assess progress.

Reviewer 5:

The project appears to have started very recently, and the reviewer commented that it does not present much in the way of accomplishments at this time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project structure appears to be collaborative, and the reviewer commented that there is an excellent opportunity for cross-project collaboration within the Joining Core Program (JCP) as well as with other DOE-funded projects.

Reviewer 2:

The reviewer noted that the team consists of three national laboratories and fully utilizes the expertise of each laboratory, such as expertise in joining processing, coating, and corrosion characterization from ORNL, friction-based fastener joint from PNNL, and X-ray synchrotron from ANL. It will be better for the team to differentiate the tasks led by ORNL and PNNL.

Reviewer 3:

Without formal industry or academic involvement, the reviewer warned that this project risks being largely confined to use in national laboratories.

Reviewer 4:

Collaboration is well explained in the documents; the reviewer suggested that perhaps collaboration with academia may be included on galvanic corrosion aspects.

Reviewer 5:

The reviewer indicated that the only reported collaboration is primarily limited to national laboratories with little to no participation by industry or academia. While the coordination among labs seems sufficient, the reviewer asserted that more collaboration from outside the national laboratories, especially more guidance from industry (beyond just periodic interaction through other JCP thrusts), would be desirable to ensure that final results are meaningful and useful to the automotive industry.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer opined that the plan going forward can have a significant impact on improving corrosion resistance of multi-material systems.

Reviewer 2:

According to the reviewer, the proposed future work meets the research goal and addresses the research challenges.

Reviewer 3:

Proposed future research fits well with the stated goals of the project. However, it was not completely clear to the reviewer how this research is intended to be used by industry to improve corrosion resistance of multi-material joints.

Reviewer 4:

The reviewer suggested that galvanic corrosion work can be shared with academia.

Reviewer 5:

The reviewer suggested that the project team consider the following points:

- Investigation of a novel fastener design (US2020/0116188), which is currently being commercialized for metal-CFRP joining by MNP Corporation.
- Plasma treatment alone is known to activate the surface and thereby enhance adhesive bonding, but it has a very short “open time,” which has industrial significance, and does not improve the post-environmental exposure adhesive bond performance.
- Application of atmospheric plasma coatings, which can be sub-micron for galvanic protection on dissimilar metal joints (refer to DOE DE-FOA-0001465 [Starfire Industries Prime]: “Atmospheric Cold Plasma Jet Coating and Surface Treatment for Improved Adhesive Bonding Performance of Dissimilar Material Joints subject to Harsh Environmental Exposure”).
- Application of a commercial laser ablation system that has commercial relevance; for example, a cover gas can be of interest technically, but production applications do not employ these. The following provides a summary of recent work: “Application of laser ablation in adhesive bonding of metallic materials: a review,” Optics and Laser Technology, 128, Aug. 2020, 106188.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that DOE is interested in GHG emission reductions. Application of lightweight materials supports this goal. In order to actualize application of the right material in the right form in the right application, it is imperative to achieve dissimilar material joints. The current strategy for such joints uses hybrid joining solutions involving adhesive bonding. The understanding of the adhesive-substrate interface under environmental exposure is imperative to joining dissimilar materials.

Reviewer 2:

Joining of dissimilar materials is an important area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. Corrosion is a critical barrier in broadening the application of dissimilar materials joints. The reviewer stated that this research aims to address this issue by modifying the bonding surfaces to improve the galvanic corrosion resistance.

Reviewer 3:

The project focuses on corrosion of dissimilar material joints, which the reviewer said is a key technical challenge for lightweight multi-material automotive structures.

Reviewer 4:

According to the reviewer, this kind of work is essential for lightweight next-generation transportation systems.

Reviewer 5:

The reviewer found this project to be very important for multi-material design of vehicles.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

Work in national laboratories is expensive, but the reviewer commented that this seems like a good investment.

Reviewer 2:

According to the reviewer, the national laboratories have enough resources to fulfill the research goals on time.

Reviewer 3:

The reviewer suggested that some allocation toward academic collaborators would be interesting (to train future scientists and engineers in this strategic work).

Reviewer 4:

It seemed to the reviewer that $3.225 million is excessive for a project that does not indicate a clearly defined path for reducing corrosion resistance of lightweight multi-material automotive structures.

Reviewer 5:

The reviewer observed that a listing of the key members, their competencies, and relative proportion of their time would be useful to assess this, given the large number of people listed on the project.

Presentation Number: mat226
Presentation Title: Machine Learning for Joint Quality and Control
Principal Investigator: Keerti Kappagantula (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

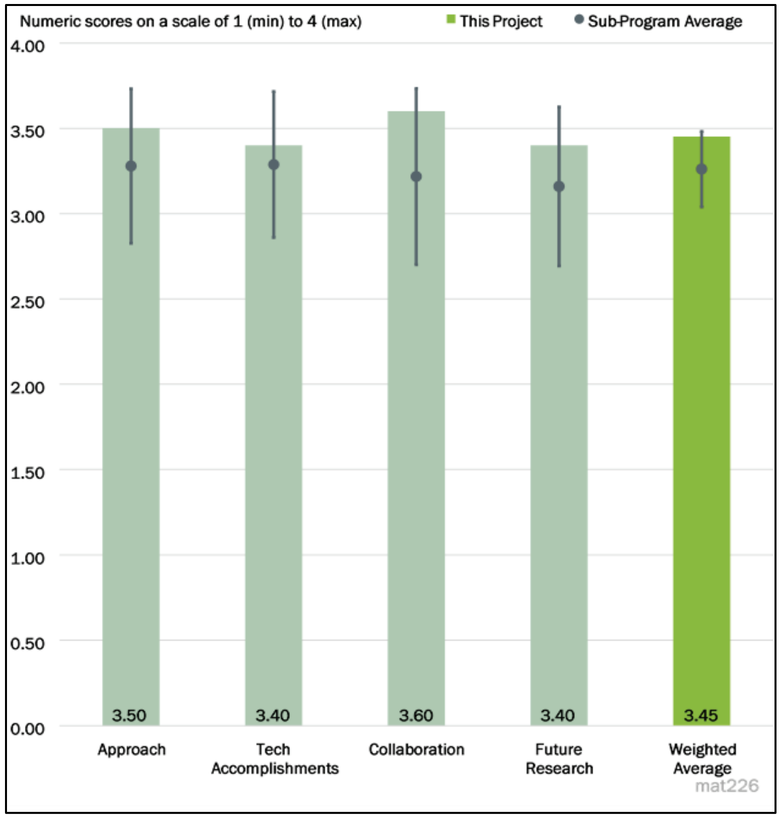

Figure 6-53 - Presentation Number: mat226 Presentation Title: Machine Learning for Joint Quality and Control Principal Investigator: Keerti Kappagantula (Oak Ridge National Laboratory/Pacific Northwest National Laboratory)

Presenter

Keerti Kappagantula, Oak Ridge National Laboratory/Pacific Northwest National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This project is leveraging a large volume of weld data provided by an industrial partner, GM, for ML algorithm development. The approach adopted here is excellent. The reviewer found that Phase 1 is very well planned as evidenced by the fact that the team was able to obtain the datasets from GM and begin analysis in a short amount of time.

Reviewer 2:

The approach of evaluating resistance spot weld (RSW) joints provided by GM to evaluate the effect of process parameters and material properties on weld properties and to develop ML models from those data is a logical approach, according to the reviewer.

Reviewer 3:

Identifying critical process parameter during dissimilar materials joining is very important to improve joint quality. The team is using joint performance data provided by GM and mining the data to optimize RSW process. The reviewer said that it will deliver understanding of the process-properties relationship including weld feature-properties relationship.

Reviewer 4:

This is an important approach to "tune" welding and other processes using AI and ML processes. It was not fully clear to the reviewer how this work is distinguished from the many neural-net or ML approaches that are now becoming common.

Reviewer 5:

ML is an effective approach to link the welding process, microstructure, and joint performance data. More details could have been given on the ML approach. ML will link process to joint performance by PNNL and microstructures to joint performance by ORNL. How to link the process to microstructure was unclear to the reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

This project is progressing well so far. The 20,000-weld datasets provided by GM will certainly enable some interesting analysis and are already supporting development of ML algorithms. So far, the ML algorithm is showing some predictive ability (and hopefully the correlation will be improved as the project progresses). This is not an easy thing to do, and the reviewer stated that the team is undertaking it with a solid approach. The team has made good progress in less than 1 year of effort.

Reviewer 2:

PNNL has processed numerous steel/Al joints, and ORNL has characterized the structural features of those joints. The team has also reviewed and categorized more than 20,000 datasets for GM for deep ML. About 60 material combinations and stack-up coating, adhesive, welding schedule, and bake conditions were studied. The team then evaluated weld performance peak load, extension at peak load, energy, and fracture mode under different loading and mechanical property testing conditions. The team has made a good start, and the reviewer had high expectations for this team.

Reviewer 3:

The reviewer said that the two team members have accomplished two milestones on each side, and the process is on the right track.

Reviewer 4:

This reviewer indicated that the project seemed to be off to a very good start. The work conducted so far shows meaningful progress at accomplishing the stated goals of the project.

Reviewer 5:

The reviewer remarked that good results are coming from the project. Hopefully, detailed results will be published in the coming periods.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This project is a great example of an effective collaboration between national laboratory and industrial partners. For one, the reviewer was impressed by the sheer volume of data that GM has provided to the lab partners for use in ML algorithm development. This contribution of rarely available data is an outstanding asset for this project, and the team appears to be leveraging it well. In addition, the project team plans to coordinate with GM on weld schedules for validation. Overall, the reviewer applauded this collaboration as excellent.

Reviewer 2:

The approach and the accomplishments thus far appeared to the reviewer to indicate that the collaborators are working well together and will hopefully lead to good performance throughout the remaining bulk of the project.

Reviewer 3:

The team consists of two national laboratories and one industrial partner. PNNL and ORNL will work with the weld data provided by GM. The co-PIs' groups at PNNL and ORNL should also have their weld data. The reviewer wanted to know if one of the groups plan to use its data as model validation or as part of model development.

Reviewer 4:

This reviewer observed good collaboration, although it seemed that the PNNL and ORNL efforts are somewhat duplicative, despite a more physics base at ORNL. It is good to see explicit industry involvement.

Reviewer 5:

The reviewer noted that the partnership with GM via a CRADA is very good. The reviewer hoped that it becomes productive as the reviewer was not sure what new GM would learn from this process. GM has the data, and it would be difficult to believe that GM has not already mined such a huge dataset.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer stated that this kind of work has a clear future, and the plan shows this well.

Reviewer 2:

The reviewer commented that the proposed future work meets the research goal very well.

Reviewer 3:

According to the reviewer, the proposed future work seems to be a logical extension of existing work and should assist in producing accurate models to improve multi-material weld reliability.

Reviewer 4:

The team plans to mine the data obtained during Phase 1 of the program (JPC 1). The reviewer hoped that those data are available for the other teams, too.

Reviewer 5:

Phase 1 future research plans seem appropriate and well aligned with project objectives. The reviewer found the Phase 2 future research plans to be a bit vague, however. The future work tasks listed for Phase 2 on Slide 14 do not yet appear to justify a 2-year effort. This will need some fleshing-out prior to the planned start of work in the fall.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Efficient joining of multi-material components in a vehicle is very critical. Also, the joints must exhibit significant corrosion resistance. Therefore, the reviewer stressed that this research is highly relevant.

Reviewer 2:

Joining of dissimilar materials is a critical area in advanced manufacturing for DOE to reduce the structural weight and improve component performance and energy efficiency. The reviewer commented that ML will accelerate the understanding of process-structure-performance relationships and the development of dissimilar material welding processes.

Reviewer 3:

The reviewer indicated that mass reduction through multi-material systems is essential and done well here.

Reviewer 4:

According to the reviewer, the project supports DOE objectives of reliable joining of dissimilar material joints, in this case Al to steel.

Reviewer 5:

The reviewer said that this project directly supports DOE objectives in multi-material joining.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the national laboratories and the industrial partner have enough resources to fulfill the research goals on time.

Reviewer 2:

Project is progressing well, and resources (computational, laboratory, and monetary) appeared to the reviewer to be sufficient.

Reviewer 3:

The reviewer stated that the accomplishments thus far provide a good indication that the available resources will be sufficient for successful completion of the stated future research goals.

Reviewer 4:

The team has met specific milestones with given, allocated resources, according to this reviewer.

Reviewer 5:

The Overview slide does not give the broad scope, nor the full budget and fraction performed. It was a little hard for the reviewer to tell whether the resources were sufficient.

Presentation Number: mat227
Presentation Title: Prediction of Aluminum/Steel Joint Failure
Principal Investigator: Chris Smith (Pacific Northwest National Laboratory/General Motors Company)

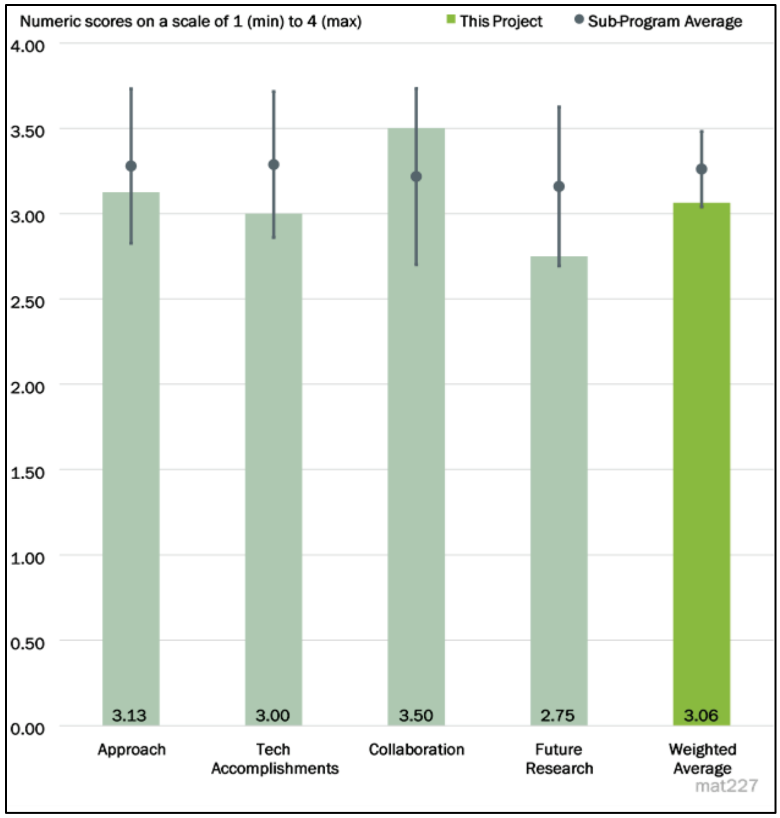

Figure 6-54 - Presentation Number: mat227 Presentation Title: Prediction of Aluminum/Steel Joint Failure Principal Investigator: Chris Smith (Pacific Northwest National Laboratory/General Motors Company)

Presenter

Chris Smith, Pacific Northwest National Laboratory/General Motors Company

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

75% of reviewers felt that the project was relevant to current DOE objectives, 25% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 50% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The approach seemed to the reviewer to be a logical progression from producing actual physical weld coupons, testing and characterizing the joints, modeling, and validation of the models.

Reviewer 2:

The reviewer stated that the primary objective of this project is to develop fine-resolution mechanical property data in and around the weld nugget in order to support predictive model development. The project roadmap demonstrated a solid approach, though some challenges unfolded during the project itself that required pivots from the original plan.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Reported accomplishments indicate good progress toward achieving the project's stated goals of predictive modeling of Al to steel joint failures, but the reviewer warned that there are challenges remaining to achieving the desired level of accuracy.

Reviewer 2:

The reviewer noted that the project team ran into challenges with several of their planned approaches, including micro-digital image correlation (DIC) and nanohardness testing. The team also experienced some delays due to COVID-19. In light of these challenges, the team pivoted to alternate characterization techniques (topographical microhardness mapping and tensile testing), which yielded some interesting results, though the team obviously lost the resolution it was hoping for in a move from nanoscale to microscale to macroscale techniques. The team also increased its focus on simulation work that could be performed remotely during COVID-19 (in lieu of experiments). The simulation work showed decent predictive capability, and the team has identified a number of key factors that warrant further exploration, such as residual stresses.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, this project seems to be a good collaboration between PNNL and GM with good coordination between the partners. While PNNL is the funded PI, GM (cost share industrial partner) seems to have made a lot of key contributions to this work, including performing a large fraction of the experimental work.

Reviewer 2:

This reviewer observed good collaboration between GM and PNNL as indicated by reported progress to date.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Proposed future research is logically focused on developing solutions to challenges encountered in the project to date, according to the reviewer.

Reviewer 2:

The reviewer remarked that there are some good ideas for future work that would align well with project objectives; however, near exhaustion of funding and COVID-19 delays have been identified as a barrier to pursuing some of the identified work and overcoming the remaining technical challenges.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer stated that the project focuses on predicting dissimilar joint failure in Al to steel joints, which is likely to be the most prominent joint configuration in lightweight, multi-material automotive structures in the near future.

Reviewer 2:

The reviewer asserted that this project supports DOE objectives in multi-material joining.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that the project team has nearly exhausted their funding, in part due to COVID-19 delays and impacts and in part due to unexpected challenges with the experimental work. As a result, the team had to scale back the scope of the effort. The team will likely need to leave some interesting findings (such as the residual stress questions) unexplored.

Reviewer 2:

According to the reviewer, the project report identifies “Limited funding remaining in relation to remaining challenges” as one of the remaining barriers to successful completion of the project objectives.

Presentation Number: mat228
Presentation Title: New Technologies for High-Performance Lightweight Aluminum Castings
Principal Investigator: Paul Jablonski (National Energy Technology Laboratory/General Motors Company)

Presenter

Paul Jablonski, National Energy Technology Laboratory/General Motors Company

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

80% of reviewers felt that the project was relevant to current DOE objectives, 20% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

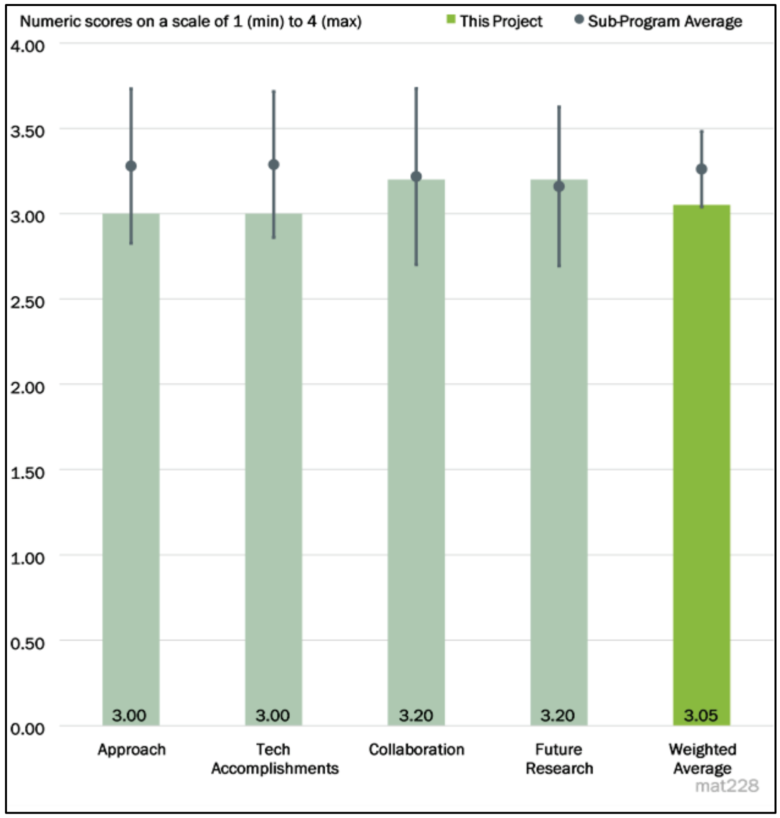

Figure 6-55 - Presentation Number: mat228 Presentation Title: New Technologies for High-Performance Lightweight Aluminum Castings Principal Investigator: Paul Jablonski (National Energy Technology Laboratory/General Motors Company)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer called the approach simple but appropriate for this project. The team will develop the pressure-assisted precision sand casting (PAPSC) process on a simple plate mold and then confirm the process steps on a production-like, water cooled deck face insert. Concurrently, the casting material microstructure and mechanical properties including tensile, fatigue, creep, and thermal mechanical fatigue will be characterized to guide process development.

Reviewer 2:

Within the framework of the minimal details provided, the approach seemed sound to the reviewer. The PAPSC approach is intriguing for reduction of flaws. A more thorough description of the unique nature of the National Energy Technology Laboratory (NETL) casting capabilities being used would be helpful next year.

Reviewer 3:

The reviewer commented that the approach is generally good. Some information about the mechanical testing process of the cast component to be adopted by the PIs (methodology and where samples will be taken from for a representative set of results) will be beneficial. Central to this project is increasing strength and fatigue resistance by greater than 25%.

Reviewer 4:

The project approach is aligned with addressing the technical barriers and targets.

Reviewer 5:

This project is not investigating novel technology or alloy systems. Pressure-assisted casting technology has been put into production in the past (e.g., Cosworth process). It was difficult for the reviewer to see where this project is addressing technology barriers other than potentially the water-cooled chill. The addition of novel technology such as rapid sand core printing or a novel alloy might be an improvement. However, given the short timeline, it is unclear that there will be time for a pivot.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Excellent technical accomplishments on progressing the die design and the process development based on numerical simulations. According to the reviewer, the efforts to cast and characterize the initial prototype castings are excellent. The development of the PAPSC process developed at GM is a crucial part of the accomplishments.

Reviewer 2:

Given the constraints of lockdowns related to COVID-19, the progress appeared to the reviewer to be adequate for the technology deliverables.

Reviewer 3:

The reviewer stated that there were very few results to assess thus far, due to unavoidable schedule delays related to COVID-19. The development of the mold chill and design of the casting process and system seem to be the primary progress to date.

Reviewer 4:

Progress is generally good, considering that it was hampered by the COVID-19 global pandemic. The reviewer expected that work will accelerate once the pandemic restrictions are eased.

Reviewer 5:

Technical accomplishments were made and presented; however, the reviewer noted that COVID-19 had affected progress in 2020.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer indicated that collaborators seemed to be working well together, and further noted that work is evenly distributed.

Reviewer 2:

The reviewer said that Coordination among the partners is good.

Reviewer 3:

The project appeared to the reviewer to coordinate and collaborate across the team.

Reviewer 4:

The strong accomplishments indicate excellent collaboration between the partners, NETL, GM, and Eck Industries. The reviewer would have liked to see a chart or table with the typical interactions (i.e., weekly, monthly, and quarterly) and a clear list of roles and responsibilities plus a “gives and gets” table showing the interactions as the cylinder head castings move forward.

Reviewer 5:

The team of NETL, GM, and Eck appear to be well positioned for success, but at this stage of progress the quality of collaborations was not yet clear to the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer remarked that there is an outstanding plan to cast, then characterize and test prototype cylinder heads. The plan includes microstructure and thermo-mechanical property characterization. The addition of dynamometer testing of the prototype cylinder heads is an excellent addition to the overall plan.

Reviewer 2:

The project plans to meet planned deliverables by working into 2022 on a no-cost extension. The reviewer suggested that future work could also consider or model the projected tool life for the head deck face chill.

Reviewer 3:

According to the reviewer, the proposed future research does appear to address the objectives of the project. A no-cost extension would give the required time to complete the work.

Reviewer 4:

The reviewer asserted that the proposed work is intriguing and if successful could be remarkably impactful to reduce casting flaws and improve reliability and fatigue life in highly stressed cast components.

Reviewer 5:

The future work proposed will contribute to the goals and milestones of the project. A cost analysis of the part produced by the process is warranted if that has not already taken place to confirm a favorable cost-benefit. The reviewer reference earlier comments and said that provision of more detail about the mechanical testing to be performed on the part(s) would be helpful.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer affirmed that higher quality castings would be a key step toward enabling higher power densities and improved efficiencies in future ICE and hybrid vehicles.

Reviewer 2:

The reviewer remarked that achieving the stated goals will lead to better energy efficiency and likely to higher engine durability.

Reviewer 3:

The reviewer stated that the project is relevant to deliver high-quality powertrain casting for smaller displacement engines with the same power.

Reviewer 4:

The reviewer observed that the improvements in strength and fatigue resistance will enable higher compression ratios leading to improved fuel efficiency.

Reviewer 5:

This project as written is not novel. The PAPSC process and the use of chills with a standard Al alloy for ICE castings has been done in prototyping and production for many years. The idea of using chills and characterizing the effect on microstructure and mechanical properties performance in cast Al alloys has been well established in the literature. There are several areas of research in the sand-casting area that are novel and could meet the goals of the DOE objectives. The reviewer suggested that new Al alloys, a novel sand core-making process, and large thin-walled castings using PAPSC are all areas that might be of interest.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, funding appears sufficient to meet project goals as stated.

Reviewer 2:

The reviewer said that an appropriate level of resources has been applied to this project.

Reviewer 3:

The reviewer noted that the remaining resources are sufficient to complete this project, which has been delayed due to COVID-19 safety protocols.

Reviewer 4:

The funds appeared to be sufficient to the reviewer. More information is required to make a better assessment. Amount of work completed was stated, but the amount of money spent was not.

Reviewer 5:

This reviewer described project resources as sufficient.

Presentation Number: mat229
Presentation Title: Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components
Principal Investigator: Govindarajan Muralidharan (Oak Ridge National Laboratory/FCA LLC)

Presenter

Govindarajan Muralidharan, Oak Ridge National Laboratory/FCA LLC

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

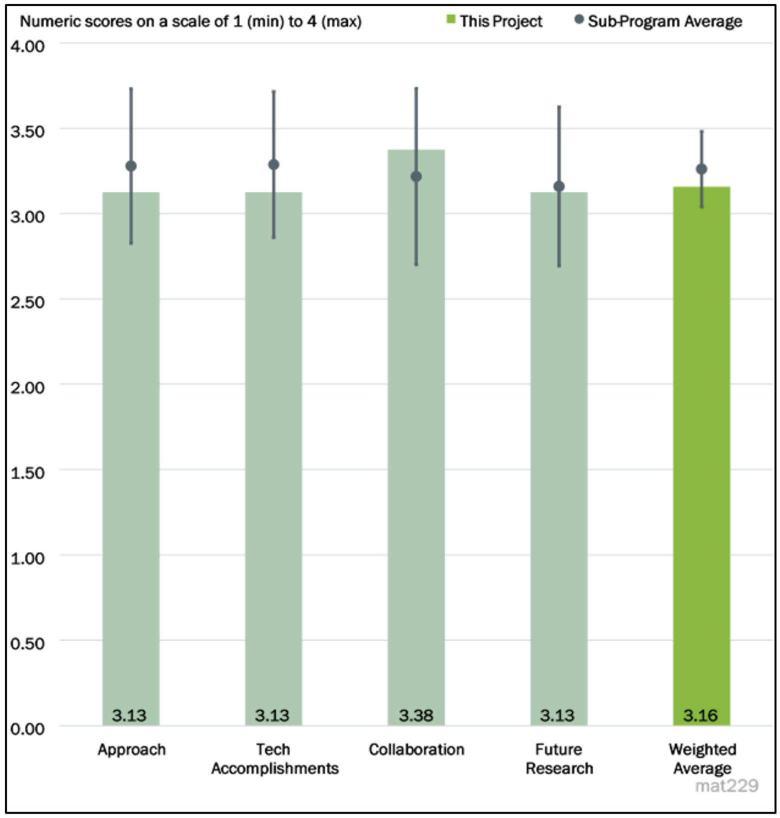

Figure 6-56 - Presentation Number: mat229 Presentation Title: Development of a Novel Magnesium Alloy for Thixomolding of Automotive Components Principal Investigator: Govindarajan Muralidharan (Oak Ridge National Laboratory/FCA LLC)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer noted that the stated objectives are to develop a new Mg alloy that will process easily in thixomolding™ and will have the desired elongation and mechanical properties of an AM60 alloy. The project is well designed to meet those objectives. The project team utilizes an ICME approach and some very targeted property selection to achieve that goal.

Reviewer 2:

Performing alloy design to match a thixomolding process is a justifiable task. The application presented, a spare tire carrier, however, lacks the requirement for high ductility that the thixomolding process naturally entails. The details of the alloy design strategy via CALPHAD were not entirely clear to the reviewer. Also, the current state of the project with regard to meeting all project targets (a combination of processability, strength, and ductility) was not clearly presented.

Reviewer 3:

The approach for the project is well defined and designed to overcome the potential barriers related to use of Mg alloys for automotive applications. The project is using computational modeling, lab scale heats, ingot fabrication, characterizations, component fabrication, and testing. The project will also be addressing the corrosion behavior of the fabricated component. The pathway presented is appropriate for the demonstration of the thixomolding fabrication approach for Mg alloys with improved properties. It was not clear to the reviewer why corrosion tests are planned for the component level only. It may have been better to perform some corrosion tests at the ingot scale as well.

Reviewer 4:

The approach is sound and will lead to the goals being achieved, according to this reviewer.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the project has made excellent progress. The new alloy composition, as determined by modeling, has been fabricated. Material properties (ductility and strength) are superior to the current commercial alloys. The progress is on track per the project tasks.

Reviewer 2:

The researchers have found some candidate alloys and have stated they are on track for physical testing of a larger component. The timing for completion of evaluation of components produced using the new alloy seemed very tight to the reviewer. However, other than corrosion testing, it could be complete in the next 8 months.

Reviewer 3:

The reviewer referenced earlier comments and stated that the exact status of the project remains vague.

Reviewer 4:

Work progress is good considering the impact of the COVID-19 pandemic on work execution. The reviewer commented that no corrosion resistance data were presented (marked as complete March 2021 on Slide 8) for alloy downselection. Downselection criteria used for corrosion and mechanical properties would be helpful.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The project appeared to the reviewer to have the appropriate number of participants. All key players appear to be capable of achieving project goals. There are no apparent gaps.

Reviewer 2:

The project team of ORNL, FCA, and Leggera Technologies complements the various tasks of the project. The reviewer found that specific roles of each partner have been clearly defined. Progress on the project reflects that there is good collaboration between the team members.

Reviewer 3:

As far as presented, the reviewer stated that there did not appear to be any shortcomings regarding cross-team collaboration.

Reviewer 4:

Collaboration is good, according to the reviewer.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The presented plan is fine with the reviewer.

Reviewer 2:

Overall, the project has been very well planned. The future tasks are well laid out. One comment from the reviewer, as alluded earlier, is that there should be some corrosion testing conducted early on (at lab-scale heats) rather than doing it once the component is fabricated.

Reviewer 3:

In general, the project seems to have a identified a few alloys that could be used for evaluation if a lead alloy does not work well. However, it was difficult for the reviewer to evaluate since the candidate alloy chemistries were not identified. It is not clear if an existing alloy was simply tweaked or if new alloy systems were attempted. Other issues, such as constituent availability or recyclability, were not evaluated. While there has been some preliminary lab-scale testing, the behavior of the alloy candidates in actual thixomolding trials has not been evaluated. Other factors could show up with a shortened time frame to complete. There is some risk to the project completing objectives on time.

Reviewer 4:

This work seeks to extend the knowledge gained in fabricating wheel holders from new alloy chemistries to other auto parts. The reviewer suggested that a listing of those auto parts and the target properties and parameter values would be helpful (a simple table would suffice). A basic cost analysis for each part using the new chemistries and relevant fabrication methods would be beneficial to determine viability of these extensions and to support the PIs' conclusions.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer said that Mg is a potential candidate material for lightweight vehicles and EVs. Development of fabrication methods and materials with improved mechanical properties (ductility and strength) is critical for their commercial use. In that respect, the project is highly relevant to DOE objectives for fuel reduction and environmental benefits.

Reviewer 2:

This project does address lightweighting in large vehicle components by addressing some of the challenges of thixomolding of Mg parts. The ability for Mg components to replace high-pressure die casting (HPDC) high ductility Al components in structural applications can contribute significantly to lightweighting the glider. Die casting of Al parts tends to require special alloys and post-process heat treatments, which are not required by Mg. However, challenges with die casting Mg remain that can be solved using the thixomolding process. This could become an enabler, and the project specifically uses a thin-walled part to assist in this evaluation, according to the reviewer.

Reviewer 3:

The reviewer noted that thixomolding offers great opportunities for lightweighting, and thus this project lies within the scope of the DOE.

Reviewer 4:

The reviewer stated that weight reduction of auto bodies and components is essential for fuel efficiency in autos.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer indicated that the resources are sufficient if the downselected alloy is successfully thixomolded.

Reviewer 2:

The reviewer reported no shortages of resources.

Reviewer 3:

Project resources are sufficient and adequate, according to the reviewer.

Reviewer 4:

Resources seem sufficient. The amount of work done was presented, but the amount of money spent was not presented, so it was difficult for the reviewer to make the fund sufficiency assessment.

Presentation Number: mat230
Presentation Title: Laser Powder Bed Fusion Parameter Development for Novel Steel and Aluminum Powders Using In Situ Synchrotron Imaging and Diffraction
Principal Investigator: Aaron Greco (Argonne National Laboratory/General Motors Company)

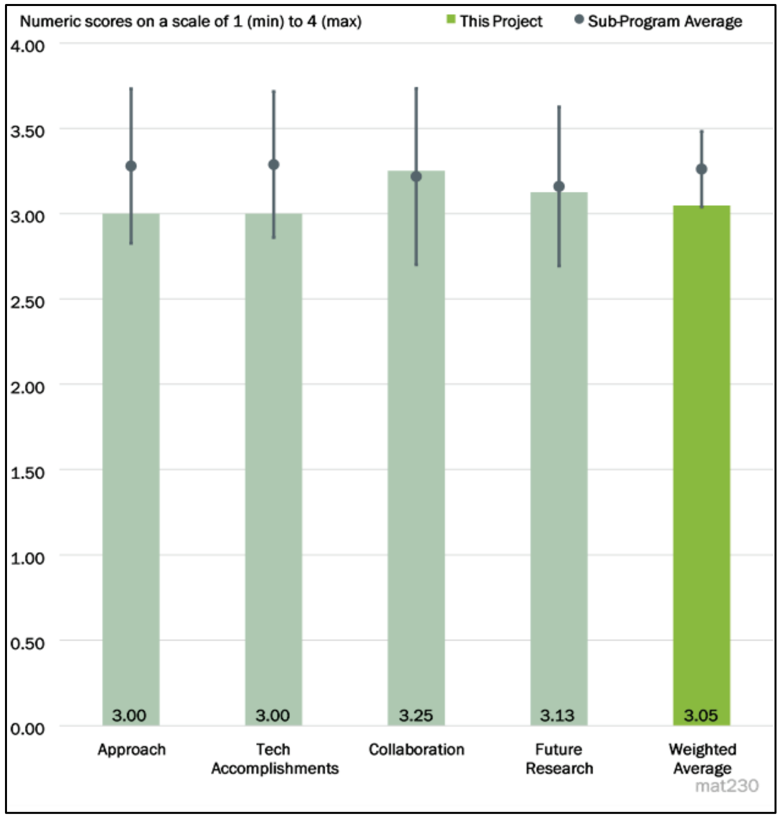

Figure 6-57 - Presentation Number: mat230 Presentation Title: Laser Powder Bed Fusion Parameter Development for Novel Steel and Aluminum Powders Using In Situ Synchrotron Imaging and Diffraction Principal Investigator: Aaron Greco (Argonne National Laboratory/General Motors Company)

Presenter

Aaron Greco, Argonne National Laboratory/General Motors Company

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

This work is providing valuable experimental results to complement local thermal predictions from simulation and will be important for assisting in determining alloy compositions and laser processing parameters that work best to meet the goals of higher performance and lower cost alloy systems. The reviewer noted that the correlation of the in situ parameters and actual parameters used in the laser power bed fusion (LPBF) process will be important.

This work appears to address keyholing porosity, but it was difficult for the reviewer to see if it also addresses lack of fusion porosity. More detail on hot tearing would be useful as well.

Reviewer 2:

The reviewer said that the approach is good.

Reviewer 3:

This project aims to accelerate alloy development through observation of the LPBF process through in-situ X-ray imaging. Considering the challenge associated with developing new alloys for LPBF and for a smaller

Lightweight Materials Consortium (LightMAT) project, this effort appeared to the reviewer to lack focus. Too many alloys and applications are being targeted simultaneously. In addition, given the very local nature of the in-situ technique, it is a stretch to claim that this effort can lead to substantial progress.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The reviewer found the technical accomplishments to be reasonable, given the obstacles such as lab and beamline closure faced by the team members due to COVID-19.

Reviewer 2:

A lot was accomplished even with stay-at-home orders, but there still appear to be setbacks. The reviewer warned that finishing within the project timing may be difficult.

Reviewer 3:

Technical accomplishments are good given work restrictions imposed by the global COVID-19 global pandemic. The reviewer proposed the following for the project team to consider:

- At least mention the method of AM used to produce the parts. The methodology matters.
- A word on process control. How is it being done? All the analyses will mean nothing if the part coming off the production line is different (e.g., microstructure and mechanical and chemical properties) all the time.
- Please comment on pore density and distribution where and when it occurs (surface, middle, through thickness, evenly distributed, etc.).
- Consider listing the possible parts the new chemistries and AM technique (optimized printing parameters) being evaluated will be extended to and why. A basic cost analysis will be beneficial to support the conclusions of the PIs.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

Collaboration seemed effective to the reviewer. The alloys studied were relevant to the automotive partner. The cost-sharing tasks appear to be very equivalent.

Reviewer 2:

Good synergy seems to exist between ANL and GM, according to the reviewer.

Reviewer 3:

This reviewer remarked that collaboration between the national laboratory and university partner seemed to be progressing smoothly.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer asserted that the remaining modeling work and comparison to the in-situ results will be important. Since alloy #2 will be a very different alloy, the modeling may be challenging.

Reviewer 2:

Not much was said about fatigue and strength evaluations of the alloys and printed parts. The reviewer inquired about how these are being evaluated in this project and correlated to the processing parameters.

Reviewer 3:

The reviewer commented that future research can once again benefit from focusing the project effort.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

According to the reviewer, this project addresses fundamental ICME for automotive relevant alloys (ferrous and Al) that will be enablers for lightweighting from a design perspective and a business case perspective.

Reviewer 2:

The reviewer remarked that reduction of component weight and increased durability are central to cost reductions and efficiency gains in auto production.

Reviewer 3:

The reviewer commented that the project is relevant in that new LPBF alloys have the potential to change the landscape of powertrain applications.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The resources for beam time appeared to be sufficient to the reviewer.

Reviewer 2:

Project resources appeared sufficient to the reviewer.

Reviewer 3:

Funding appears to be sufficient. There is no mention from the PI about the percentage and/or amount of money spent versus the amount of work and/or scope completed. It was therefore difficult for the reviewer to assess whether the funds are sufficient.

Presentation Number: mat232
Presentation Title: Light Metals Core Program - Thrust 1 – Selective Processing of Al Sheet
Principal Investigator: Darrell Herling (Pacific Northwest National Laboratory)

Presenter

Darrel Herling, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 0% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

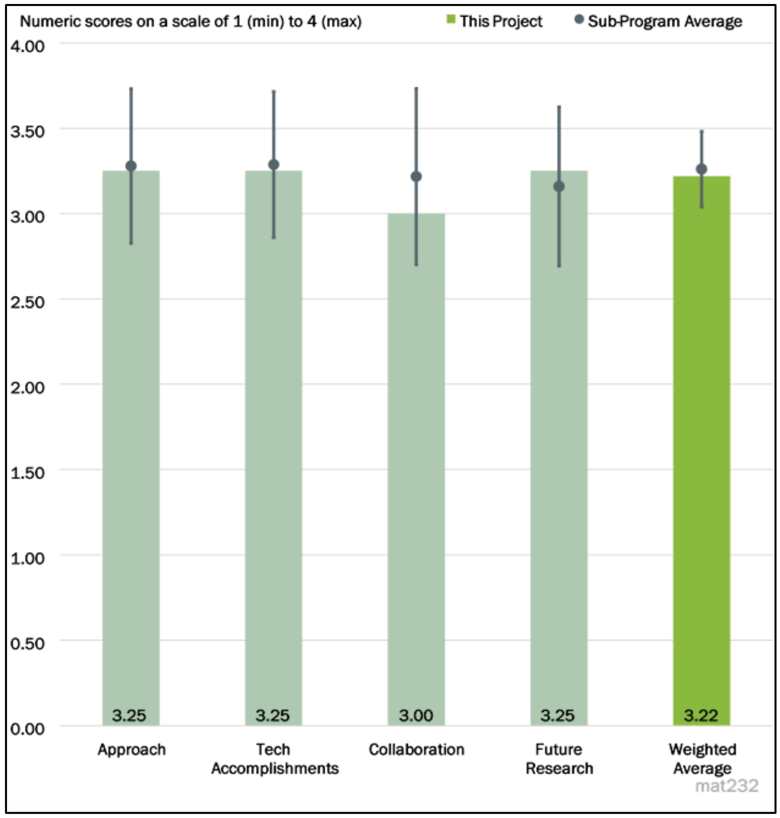

Figure 6-58 - Presentation Number: mat232 Presentation Title: Light Metals Core Program - Thrust 1 – Selective Processing of Al Sheet Principal Investigator: Darrell Herling (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer stated that this high-level project approach is aligned to address stated barriers and technical targets to implementation of Al and Mg in automotive applications using technologies in solid-phase processing, AM, and thermochemical treatments.

Reviewer 2:

The reviewer stated that this project is developing enabling technologies for Al sheet with three tasks underway—one on composite rolling process, a second on AM reinforcement, and a third on surface modification technologies to change properties. Of these, the first one is not very important for the sheet development because extruding a tube and converting it to a sheet is very long process and will not justify the cost. The reviewer asserted that changing the local properties or size is a good value proposition, but the approach needs to be changed. The AM process for supporting structure is good concept; as the interface characterization and optimum choice of material need to be developed, the proposed approach is good. Surface or structure modification through processing is also good.

Reviewer 3:

The projects are set up to loosely complement each other as various ways to selectively reinforce Al sheet materials. This approach is important because each of processes can have use in specific situations. From a mechanical performance and initial processing perspective, the projects do seem to address the challenges. However, there do seem to be gaps in material compatibility using different alloys and effects for other processing aspects (coatings, corrosion, and recyclability) that do not seem to be taken into account. Perhaps that is outside the scope, but consideration should be made on the alloy combinations from this perspective. Also, Project 1A is designed such that the extrusion would subsequently be formed; however, it was not clear to the reviewer if Project 1C (which has a major focus on sheet forming) is going to be addressing those issues or if Project 1A will use lessons learned, etc. Coordination here is not apparent.

Reviewer 4:

The reviewer noted that this project has three sub-projects, so the approach varies slightly among the three sub-projects. The concern that the reviewer had is that it seems that the researchers proposed the work based on their available equipment, rather than identifying the problems that the industry has and then looking for the best solutions. For example, producing automotive sheet using the Shear Assisted Processing and Extrusion (ShAPE™) process does not make sense from the cost point of view. On the other hand, multi-alloy extrusion using ShAPE makes more sense.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

According to the reviewer, the projects seem to be making good progress. Regarding Project 1A, the project has developed the tooling and done some initial extrusions but no forming of microstructure. This seems on track for the project. A focus on the variable thickness or varying the properties using changes in processing conditions during the extrusion might be a more fruitful route than changing alloys within the same extrusion and more in keeping with the goal of recyclability for sheet production.

Regarding Project 1B, this reviewer indicated that the project team has downselected the filler material but will not complete the coupon trials until September. This seems on track for the project.

Regarding Project 1C, the reviewer noted that this project seems to be on track for the first year.

Reviewer 2:

The reviewer had comments about each project. Specific to Project 1A, the reviewer stated that multi-extrusion work is showing good progress. Regarding Project 1B, only initial single bead deposits have been made. Alloy selection and interfacial strength are the key to the success of this project. Further, the reviewer observed the most progress in Project 1C and suggested that a demonstration part is needed to validate the improvement.

Reviewer 3:

Development in extrusion is good but the reviewer said that it will not justify sheet development; variable thickness and multi-alloy extrusion are quite significant and can be developed further for extrusion itself.

The project has just started and, for the time, the progress in the tasks is reasonable. The cost of using FSW and other processes to soften the edges and improve bendability needs to be estimated.

The work on developing a new standard to evaluate bending is a good task suitable for national laboratory activities.

Reviewer 4:

This is a new project; hence, the reviewer found the accomplishments to be preliminary with experiment planning, material collection, and initial proof of concepts.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The core project team appeared to the reviewer to share resources and meet frequently.

Reviewer 2:

The reviewer commented that collaboration is generally good but could be more open to broader participation of the light metals community.

Reviewer 3:

Cooperation between three labs is good with tasks distributed based on the strength of teams at labs. As of now, there are no industrial partners, but there is advice from various industry leaders. The reviewer encouraged the team to focus efforts on involving industry partners to assess the feasibility of the processes under development.

Reviewer 4:

It appeared to the reviewer that there could be more coordination, particularly between Project 1A and Project 1C1 with the bending and unbending rolls development and the goal of cutting and forming the extrusions into sheets. These projects seem to be loosely complementary. Also, since the stated goal is to reduce alloys, it would be good to see more coordination around alloys used in the three projects.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer called this a very strong plan for novel and unique manufacturing technology development for Al and Mg.

Reviewer 2:

The reviewer observed that it would be great to have demonstration parts from industry.

Reviewer 3:

All these projects need to be investigating aspects of scaling up the technology. Some deliverables around speed, output, and repeatability would be useful for the reviewer to see.

Reviewer 4:

The focus on the extrusion process needs to be modified as it may not be the best route for sheet making, or, the reviewer suggested, the team should change the focus of the project to all thermo-mechanical processing (TMP) routes.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer opined that Al sheet (and, to a certain extent, extrusions) will contribute significantly to weight reduction for EV platforms. Extending the range or making smaller batteries will improve the energy density and performance of these vehicle. Work to improve formability and performance of sheets will contribute to the DOE objectives.

Reviewer 2:

Localized reinforcement in sheet materials is important for lightweighting strategies overall. The reviewer stated that this work investigates several novel technologies to address that capability.

Reviewer 3:

According to the reviewer, such new technology is needed to address the limitations to the manufacturing and use of Al and Mg in automotive applications.

Reviewer 4:

The reviewer's overall impression of the "Light Metals Core Program," not just this project, is that this program seems an "add-on" to existing programs at the three national laboratories. There are no strategic analyses of what challenges the automotive industry is facing in the light metals areas and what key scientific problems this program is trying to solve. Therefore, there are a bunch of ideas (sub-projects) loosely assembled together, which are based on the existing equipment and capability rather than specific problems that the industry is facing. Thus, the overall program is relevant to DOE objectives of lightweight vehicles and reduced emissions but could be better aligned and more open to broader participation of the light metals community.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer stated that the projects seem to be well resourced, given the funding amount.

Reviewer 2:

The project has appropriate resources to deliver milestones, according to the reviewer.

Reviewer 3:

The reviewer indicated that enough resources are available for the tasks identified.

Reviewer 4:

Resources are generally sufficient, but the reviewer opined that they should be adjusted to focus on more successful sub-projects and drop ideas that do not work out so well.

Presentation Number: mat233
Presentation Title: Light Metals Core Program - Thrust 2 – Selective Processing of Al Castings
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

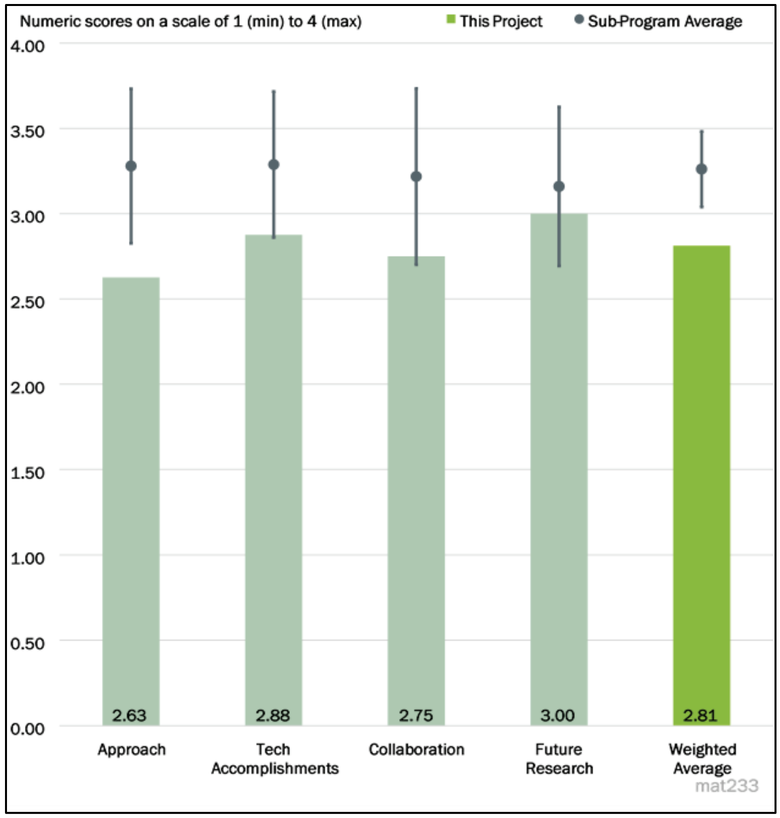

Figure 6-59 - Presentation Number: mat233 Presentation Title: Light Metals Core Program - Thrust 2 – Selective Processing of Al Castings Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The three sub-projects are generally feasible with capable teams. One of the barriers listed was “very high integrity castings can be obtained with vacuum high pressure die casting but costs are high, especially when complex designs are high.” The reviewer did do not agree with this statement. In fact, vacuum die casting is very affordable and significantly lower cost than some of the techniques in this project.

Reviewer 2:

The reviewer commented that the project is taken up to improve the performance of castings; while Tasks 1 and 3 focus on die castings, Task 2 is on metal molds. The tasks are diverse with use of FSW and AM to modify or add surfaces for die cast alloys. The focus of Task 2 is to use ultrasonic surface processing to reduce grain size and improve properties. Although the approach is good, the reviewer asserted that the use of HPDC needs to be re-evaluated. The reviewer further explained that the surface layer in HPDC components, which is less than 1 millimeter (mm) thick, is critical for performance. Modification of this could reduce the performance significantly. Larger castings from sand or permanent molds may benefit from such activities.

Reviewer 3:

The reviewer observed that the approach includes too many materials and processes investigations and too few practical applications: 380, 356, Aural 2, Aural 5, HPDC, FSW, book mold, additive, ultrasonic, etc.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

All three sub-projects have shown some modeling and preliminary experimental results, but the reviewer said that it is still too early to judge the outcome.

Reviewer 2:

Project has just started. Task 1 identified the material for testing; testing of other cast materials will be useful. In Task 2, the modeling is complete; the reviewer said that the change in cooling rates with thickness needs to be taken into account when using ultrasonic processing. For Task 3, only the planning is complete; the reviewer's comment is similar to Task 1 in that the use of other cast materials will be useful instead of only HPDC.

Reviewer 3:

The reviewer found no progress to date after two quarters.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

According to the reviewer, cooperation between labs is good; the in-kind contributions from OEM are a good start.

Reviewer 2:

The project team has demonstrated some collaboration with industry in sample sharing and modeling work. The reviewer expected more collaboration when there are more experimental results and testing.

Reviewer 3:

The reviewer saw no mention of collaborating, rather independent research efforts by ORNL and PNNL. ANL is included in the award, but tasks are not defined for work conducted by ANL.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer found sound future plans but asserted that the team needs close collaboration with industry in terms of demonstration parts and performance testing.

Reviewer 2:

The reviewer suggested that the team consider adding other cast materials for comparison purposes.

Reviewer 3:

The reviewer emphatically remarked that the project approach appears disorganized.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer remarked that Al castings will contribute significantly to energy density and long range for EVs. Local property enhancement will be useful as the castings are required to perform in various conditions on different surfaces.

Reviewer 2:

The concept of increased use of lightweight materials into the vehicle structure is a DOE objective, according to this reviewer.

Reviewer 3:

The reviewer's overall impression of the "Light Metals Core Program," not just this project, is that this program seems an "add-on" to existing programs at the three national laboratories. There are no strategic analyses of what challenges the automotive industry is facing in the light metals areas and what key scientific problems this program is trying to solve. Therefore, there are a bunch of ideas (sub-projects) loosely assembled together, which are based on the existing equipment and capability rather than specific problems that the industry is facing.

Thus, the overall program is relevant to DOE objectives of lightweight vehicles and reduced emissions but could be better aligned and more open to broader participation of the light metals community.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

According to the reviewer, the project is well funded.

Reviewer 2:

Resources are decoupled, as the reviewer said that the teams are working independently.

Reviewer 3:

Resources are generally sufficient, but the reviewer opined that they should be adjusted to focus on more successful sub-projects and drop ideas that do not work out so well.

Presentation Number: mat234
Presentation Title: Light Metals Core Program - Thrust 3 – Selective Processing of Mg Castings
Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

Presenter

Vineet Joshi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 75% of reviewers felt that the resources were sufficient, 0% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

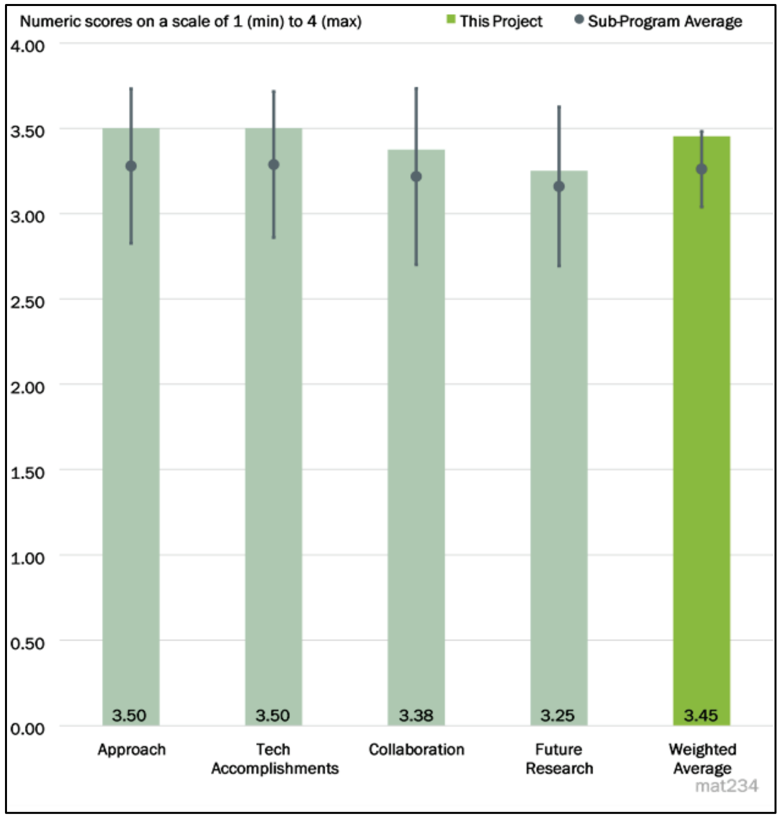

Figure 6-60 - Presentation Number: mat234 Presentation Title: Light Metals Core Program - Thrust 3 – Selective Processing of Mg Castings Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer reported that the project clearly identified the major barriers of Mg casting applications in the automotive industry and proposed two projects as the first steps of the research.

Reviewer 2:

Corrosion is the major issue to be resolved for Mg alloys used in structural applications in vehicles, and surface modification is the most direct way of improving the performance. This project is aiming to investigate many technologies to improve the performance. The reviewer commented that there is a good work plan and noted that it would be nice to have seen the current state of the art on this as the subject has been studied many times. A few solutions are available with higher cost.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

Despite a short time in the project, the reviewer indicated that it has generated some promising preliminary results in both sub-projects. Since the “skin” effect (fine microstructure and almost no porosity) on the die casting surface is critical to the mechanical properties of Mg die casting, coating solutions (retaining the die cast “skin”) are preferable to the friction stir process to improve the overall performance of Mg die castings.

Reviewer 2:

This reviewer noted that the project has started this year; progress so far is on planning and start up. Reactive surface oxidation process is well studied and could be useful to show how the new process varies from the old ones. Additionally, the reviewer explained that modeling efforts are useful in identifying the surface but need to be supported by surface analysis (assuming that it is part of another project).

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

This reviewer indicated that collaboration seemed to be good within the project team and with industry.

Reviewer 2:

The reviewer reported that DOE labs are collaborating on this and suggested that it would be useful to have an industrial advisory board to validate the assumptions and approach.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

The reviewer suggested that a demonstration part is needed for future research to validate the technologies in more complex automotive castings.

Reviewer 2:

The reviewer stated that the alloys chosen contain Al as the major element. According to the reviewer, it would be useful to have other casting alloys with other major elements (rare earth element [REE], Zr, or zinc [Zn]).

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

The reviewer opined that Mg could significantly contribute to mass reduction and solving the corrosion problem would enhance its use in vehicles.

Reviewer 2:

The reviewer’s overall impression of the “Light Metals Core Program,” not just this project, is that this program seems an “add-on” to existing programs at the three national laboratories. There are no strategic analyses of what challenges the automotive industry is facing in the light metals areas and what key scientific problems this program is trying to solve. Therefore, there are a bunch of ideas (sub-projects) loosely assembled together, which are based on the existing equipment and capability rather than specific problems that the industry is facing.

Thus, the overall program is relevant to DOE objectives of lightweight vehicles and reduced emissions but could be better aligned and more open to broader participation of the light metals community.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer said that there are enough funds and efforts for this task.

Reviewer 2:

The reviewer’s preference would be for more resources for coating solutions than FSP, which actually reduces the “skin” effect in die castings.

Presentation Number: mat235
Presentation Title: Light Metals Core Program - Thrust 4 - Characterization, Modeling and Lifecycle
Principal Investigator: Arun Devaraj (Pacific Northwest National Laboratory)

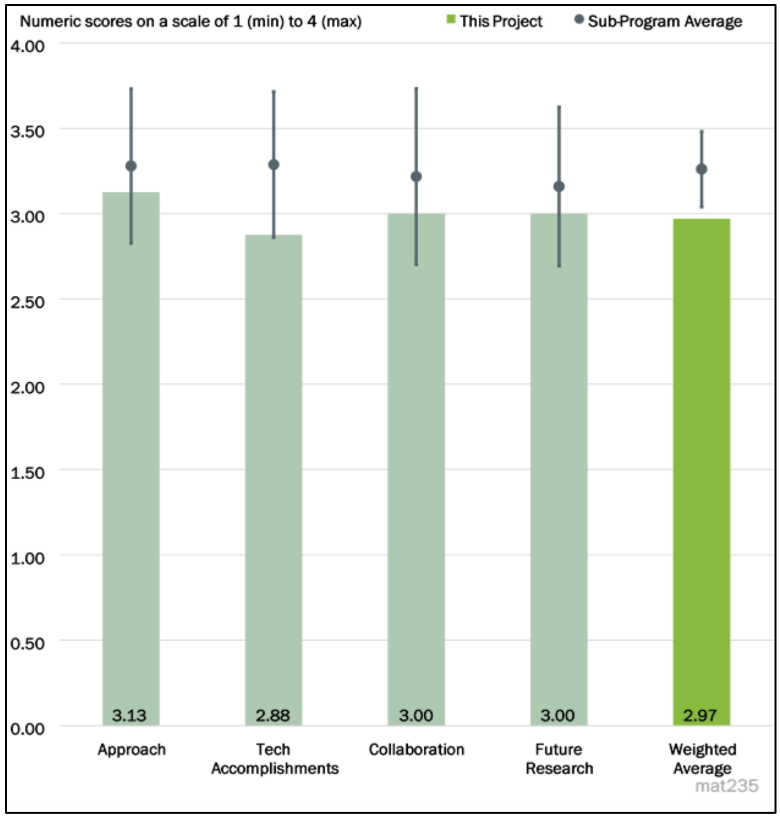

Figure 6-61 - Presentation Number: mat235 Presentation Title: Light Metals Core Program - Thrust 4 - Characterization, Modeling and Lifecycle Principal Investigator: Arun Devaraj (Pacific Northwest National Laboratory)

Presenter

Arun Devaraj, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

100% of reviewers felt that the project was relevant to current DOE objectives, 0% of reviewers felt that the project was not relevant, and 0% of reviewers did not indicate an answer. 50% of reviewers felt that the resources were sufficient, 25% of reviewers felt that the resources were insufficient, 25% of reviewers felt that the resources were excessive, and 0% of reviewers did not indicate an answer.

Question 1: Approach to performing the work—the degree to which technical barriers are addressed, the project is well-designed and well-planned.

Reviewer 1:

The reviewer said that a unique and attractive mix of equipment and expertise has been established in this effort. The approach builds on the successful model built on the PMCP from VTO.

Reviewer 2:

The project supports the other tasks of Al sheet, castings, and Mg corrosion by conducting modeling, characterization, and testing. The reviewer commented that there is good planning on experiments and models and. also life-cycle analysis (LCA) efforts on light metals.

Reviewer 3:

This project is a cross-cut thrust, so the reviewer found it to be quite broad as it includes characterization, modeling, and lifecycle. The project clearly identified barriers in light metals research and application. Compared with characterization and modeling, material lifecycle has a much smaller effort, which should be strengthened.

Reviewer 4:

According to the reviewer, the approach is a series of decoupled research projects. Each project has independent basic research value.

Question 2: Technical Accomplishments and Progress toward overall project goals—the degree to which progress has been made and plan is on schedule.

Reviewer 1:

The effort is a new start, and the reviewer indicated that the initial progress is already excellent. More attractive results are expected in the future.

Reviewer 2:

The reviewer stated that enough effort has been spent on the planning as the project is just starting. Materials have been obtained, and modeling efforts have begun.

Reviewer 3:

Both characterization and modeling projects are showing good progress. It was not very clear to the reviewer how the lifecycle research will contribute to increased recycling or increased use of secondary alloys in the automotive industry.

Reviewer 4:

The reviewer found no progress to date after two quarters.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:

The reviewer commented that most of the research in this thrust is to support projects in the other three thrusts, reflecting excellent collaboration with other project teams.

Reviewer 2:

The collaboration and co-ordination across the national laboratory team (three national laboratories) were very impressive to this reviewer.

Reviewer 3:

Internal collaboration within the teams and labs is good; planning on meetings and interactions are satisfactory. The reviewer suggested that having an industrial panel to advise will be good.

Reviewer 4:

The projects do not include collaboration, which would require coordination across a project team. According to the reviewer, each project is a separate research area.

Question 4: Proposed Future Research—the degree to which the project has effectively planned its future work in a logical manner by incorporating appropriate decision points, considering barriers to the realization of the proposed technology and, when sensible, mitigating risk by providing alternate development pathways. Note: if the project has ended, please state project ended.

Reviewer 1:

Proposed future research includes a second call for proposals. The reviewer asserted that residual stress analysis and materials lifecycle analysis are all very well thought out.

Reviewer 2:

The research is in response to other teams’ products; planning is difficult, but the reviewer said that it is managed well.

Reviewer 3:

The reviewer felt that this thrust should be open to universities and other labs with expertise in the needed areas, such as process modeling, microstructure and defect simulation, and recycling research.

Reviewer 4:

According to the reviewer, the research proposed does not include decision points, barriers, and risk assessment.

Question 5: Relevance—Does this project support the overall DOE objectives? Why or why not?

Reviewer 1:

Light metals are very important materials for vehicle lightweighting. According to the reviewer, this program will provide fundamental support to research and applications of light metals.

Reviewer 2:

The reviewer asserted that the understanding of the material performance will enable the development of new materials and processes. This will help reduce the cost and improve the use of light metals in vehicles.

Reviewer 3:

The reviewer said that the project is set up to be impactful through the LMCP and directly benefits the EERE VTO mission.

Reviewer 4:

The reviewer stated that each research topic is relevant to the DOE objective.

Question 6: Resources—How sufficient are the resources for the project to achieve the stated milestones in a timely fashion?

Reviewer 1:

The reviewer personally felt that this is the area where the national laboratories are best equipped to support the automotive industry in modeling, characterization, and recycling research, which will have long-term impacts on the automotive and light metals industries.

Reviewer 2:

The reviewer found that the funding is sufficient for the work identified.

Reviewer 3:

Resources are sufficient, according to the reviewer.

Reviewer 4:

The reviewer said that 42 people are working on the project.

Acronyms and Abbreviations

°C	Degrees Celsius
μm	Micrometer
3-D	Three-dimensional
ACMZ	Aluminum-copper-manganese-zirconium
AD	Additive manufacturing
AFA	Alumina-forming austentitic
AFRL	Air Force Research Laboratory
AI	Artificial intelligence
Al	Aluminum
Al_2O_3	Aluminum oxide (alumina)
AM	Additive manufacturing
AMIPC	Advanced Materials Intelligent Processing Center
AMR	Annual Merit Review
ANL	Argonne National Laboratory
APS	Advanced Photon Source
APT	Atomic probe tomography
ARPA-E	Advanced Research Projects Agency-Energy
ASTM	American Society for Testing and Materials
$BaTiO_3$	Barium titanate
BCC	Body-centered cubic
BMS	Battery management system
BOTTLE™	Bio-Optimized Technologies to keep Thermoplastics out of Landfills and the Environment
C	Carbon
CALPHAD	CALculation of PHAase Diagram
CCT	Continuous cooling transformation
Ce	Cerium
CEM	Composite epoxy material
CF	Carbon fiber
CFD	Computational fluid dynamics
CFRC	Carbon fiber reinforced composite

CFRP	Carbon fiber reinforced polymer
CFTF	Carbon Fiber Technology Facility
CGS	Compressed gas storage
CNC	Computer numerical control
CNG	Compressed natural gas
CNMS	Center for Nanophase Materials Sciences
CNT	Carbon nanontube
COVID-19	Coronavirus disease 2019
Cr	Chromium
CRADA	Cooperative research and development agreement
Cu	Copper
DFT	Density function theory
DIC	Digital image correlation
DICTRA	DIffusion-Controlled TRAnsformations in multi-component systems, a software diffusion module within Thermo-Calc for accurate simulation of diffusion-controlled reactions in multi-component alloy systems
DIW	Direct ink writing
DOE	U.S. Department of Energy
EBSD	Electron backscatter diffraction
EERE	Energy Efficiency and Renewable Energy
EM	Electromagnetic
EMI	Electromagnetic interference
EMSL	Environmental Molecular Sciences Laboratory
EV	Electric vehicle
FCA	Fiat-Chrysler Automobiles
Fe	Iron
FEA	Finite element analysis
FEM	Finite element method
FSLW	Friction-stir linear welding
FSP	Friction-stir processing
F-SPR	Friction self-piercing rivet
FSW	Friction-stir weld(ing)

g	Gram
GF	Glass fiber
GHG	Greenhouse gas
GM	General Motors
GVSC	Ground Vehicles Systems Center
HFR	High-rate friction rivet
HIP	Hot isostatic pressing
HPC	High-performance computing
HPDC	High-pressure die casting
HT	High temperature
HTC	High-temperature carbonization
HVR	High-velocity rivet
IACMI	Institute for Advanced Composites Manufacturing Innovation
ICE	Internal combustion engine
ICME	Integrated computational materials engineering
ILSS	Interlaminar shear strength
INL	Idaho National Laboratory
JCP	Joining Core Program
kg	Kilogram
k_p	Parabolic rate constant
kPa	Kilopascal
LCA	Life-cycle analysis
LIG	Laser-induced graphene
LightMAT	Lightweight Materials Consortium
LLNL	Lawrence Livermore National Laboratory
LPBF	Laser powder bed fusion
LTC	Low-temperature carbonization
m	Meter
M/O	Metal and oxide
MAS	Micro-alloyed steel
MAT	Materials Technology Program
MD	Molecular dynamics

MDF	Manufacturing Demonstration Facility
MFI	Materials Flow through Industry
Mg	Magnesium
min	Minute(s)
MIT	Massachusetts Institute of Technology
mm	Millimeter
Mn	Manganese
MOOSE	Multiphysics object oriented simulation environment
MPa	Megapascal
MSU	Michigan State University
MTT	Materials Technical Team
NDE	Non-destructive evaluation
NETL	National Energy Technology Laboratory
Ni	Nickel
nm	Nanometer
NREL	National Renewable Energy Laboratory
O	Oxygen
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PACE	Partnership for Advanced Combustion Engines
PAN	Polyacrylonitrile
PAPSC	Pressure-assisted precision sand casting
PE	Polyethylene
PEEK	Polyetheretherketone
PEKK	Polyetherketoneketone
PET	Polyethylene terephthalate
PI	Principal Investigator
PMCP	Powertrain Materials Core Program
PNNL	Pacific Northwest National Laboratory
PP	Polypropylene
PPS	Passenger protection system
PVDF	Polyvinylidene fluoride

Q	Quarter
R&D	Research and development
RASIC	Responsible, Approving, Supporting, Informed, and Consulted
ReaxFF	Reactive force field
ReaxFFMD	Reactive force field molecular dynamics
REE	Rare earth element
RF	Radiofrequency
RSW	Resistance spot weld
RTM	Resin transfer molding
s	Second(s)
SBIR	Small Business Innovation Research
ShAPE™	Shear Assisted Processing and Extrusion
SHM	Simple harmonic motion
SOA	State of the art
SPI	Stochastic pre-ignition
SPR	Self-piercing rivet
Sr	Strontium
SSL	Self-supervised learning
SStAC	Stainless steel alloy corrosion
STEM	Scanning transmission electron microscopy
SURF	Scale-Up Research Facility
T	Temperatue
TEA	Techno-economic analysis
TEM	Transmission electron microscopy
TFP	Tailored fiber placement
Tg	Glass transition temperature
Ti	Titanium
TiAl	Titanium aluminide (gamma titanium)
TMF	Thermochemical fatigue
TMP	Thermo-mechanical processing
TRL	Technology Readiness Level
TuFF	Tailorable universal feedstock for forming

U.S. DRIVE	United States Driving Research and Innovation for Vehicle efficiency and Energy sustainability
UCLA	University of California at Los Angeles
USAMP	U.S. Automotive Materials Partnership
USC	University of Southern California
USW	Ultrasonic spot welding
UTK	University of Tennessee-Knoxville
UTS	Ultimate tensile strength
VTO	Vehicle Technologies Office
WPI	Worcester Polytechnic Institute
wt.%	Weight percent
XCT	X-ray Computed Technology
XPS	X-ray photoelectron spectroscopy
XRD	X-ray diffraction
Y	Yttrium
YS	Yield strength
Zn	Zinc
Zr	Zirconium