6. Materials Technologies

The Vehicle Technologies Office (VTO) has a comprehensive portfolio of early-stage research to enable industry to accelerate the development and widespread use of a variety of promising sustainable transportation technologies. The research pathways focus on fuel diversification, vehicle efficiency, energy storage, and mobility energy productivity that can improve the overall energy efficiency and efficacy of the transportation or mobility system. VTO leverages the unique capabilities and world-class expertise of the National Laboratory system to develop innovations in electrification, including advanced battery technologies; advanced combustion engines and fuels, including co-optimized systems; advanced materials for lighter-weight vehicle structures; and energy efficient mobility systems. VTO is uniquely positioned to address early-stage challenges due to strategic public-private research partnerships with industry (e.g., U.S. DRIVE, 21st Century Truck Partnership) that leverage relevant expertise. These partnerships prevent duplication of effort, focus DOE research on critical R&D barriers, and accelerate progress. VTO focuses on research that industry does not have the technical capability to undertake on its own, usually due to a high degree of scientific or technical uncertainty, or that is too far from market realization to merit industry resources.

The Materials Technology (MAT) subprogram supports early-stage R&D of technologies for vehicle lightweighting and improved propulsion (powertrain) efficiency applicable to light- and heavy-duty vehicles. The MAT research portfolio supports the VTO goals of affordable transportation and energy security. Reducing the weight of a conventional passenger car by 10% results in a 6%–8% improvement in fuel economy, and similar benefits are achieved for battery electric and heavy-duty vehicles. Research focuses on activities that have a high degree of scientific or technical uncertainty or that are too far from market realization to merit sufficient industry emphasis and resources. The MAT subprogram accomplishes its technical objectives through research programs with academia, National Laboratories, and industry.

Propulsion Materials Technology supports research at National Laboratories to develop higher performance materials that can withstand increasingly extreme environments and address the future properties of a variety of relevant, high-efficiency powertrain types, sizes, fueling concepts, and combustion modes. The activity continues to apply advanced characterization and multi-scale computational materials methods, including high performance computing (HPC), to accelerate discovery and early-stage development of cutting-edge structural and high temperature materials for more efficient powertrains.

Lightweight Materials Technology supports National Laboratory 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.

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
mat118	Functionally Designed Ultra-Lightweight Carbon-Fiber Reinforced Thermoplastic Composites Door Assembly	Srikanth Pilla (Clemson University)	6-8	3.25	3.00	3.50	3.25	**3.16**
mat122	Close-Proximity Electromagnetic Carbonization (CPEC)	Felix Paulauskas (ORNL)	6-12	3.00	2.75	3.13	3.00	**2.89**
mat124	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles	Xiadong Li (University of Virginia)	6-16	3.67	3.67	3.50	3.50	**3.63**
mat125	Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber	Jeramie Adams (Western Research Institute)	6-19	3.33	3.00	3.50	3.17	**3.17**
mat126	Room-Temperature Stamping of High-Strength Aluminum Alloys	Aashish Rohatgi (PNNL)	6-22	3.00	2.75	3.25	3.00	**2.91**
mat127	U.S. Automotive Materials Partnership Low-Cost Magnesium Sheet Component Development and Demonstration Project	Randy Gerken (Fiat Chrysler Automotive)	6-24	3.38	3.38	3.63	2.75	**3.33**
mat136	High-Performance Computing and High-Throughput Characterizations toward Interfaces-by-Design for Dissimilar Materials Joining	Xin Sun (ORNL)	6-28	3.33	3.17	3.33	3.17	**3.23**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat137	Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel	Zhili Feng (ORNL)	6-31	2.63	2.88	3.13	2.75	**2.83**
mat138	Solid-State Joining of Magnesium Sheet to High-Strength Steel	Piyush Upadhyay (PNNL)	6-35	3.38	3.25	3.25	3.25	**3.28**
mat139	Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium	Keerti Kappagantula (PNNL)	6-38	3.13	3.50	2.88	3.33	**3.31**
mat142	Metal-Matrix Composite Brakes Using Titanium Diboride	Glenn Grant (PNNL)	6-41	3.17	3.42	3.25	2.83	**3.26**
mat146	Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites	Vlastimil Kunc (ORNL/Ames Laboratory)	6-46	3.13	3.25	3.13	3.00	**3.17**
mat147	Continuous-Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression Forming Process	Gabriel Ilevbare (Idaho National Laboratory)	6-50	N/A	N/A	N/A	N/A	**N/A**
mat149	Non-Rare Earth Magnesium Bumper Beams	Scott Whalen (PNNL/LBNL)	6-51	3.13	3.38	3.25	2.88	**3.23**
mat151	Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints	Adam Powell (Worcester Polytechnic Institute/ LANL)	6-55	2.88	3.00	3.25	3.25	**3.03**
mat152	A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives	Roozbeh Dargazany (Michigan State University/ NREL)	6-59	3.50	3.75	3.75	3.50	**3.66**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat153	Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints	Miki Banu (University of Michigan/ ORNL)	6-62	3.50	3.33	3.33	3.33	**3.38**
mat162	Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys	Dongwon Shin (ORNL)	6-65	3.00	3.10	3.10	2.90	**3.05**
mat163	Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components	Mei Li (Ford)	6-69	3.30	3.20	3.10	3.30	**3.23**
mat164	Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials	Michael Tonks (University of Florida)	6-73	3.50	3.40	3.60	3.40	**3.45**
mat165	Directly Extruded High Conductivity Copper for Electric Mahcines	Glenn Grant (PNNL)	6-78	3.67	3.50	3.67	3.33	**3.54**
mat166	Aluminum Purification and Magnesium Recovery from Magnesium-Aluminum Scrap	John Hryn (ANL)	6-81	3.67	3.67	3.33	3.50	**3.60**
mat167	Corrosion Mechanisms in Magnesium-Steel Dissimilar Joints	Vineet Joshi (PNNL)	6-84	3.40	3.30	3.60	3.20	**3.35**
mat168	Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Reinforced Composites	Henry Sodano (Trimer Technologies, LLC)	6-87	3.50	3.50	3.50	3.33	**3.48**
mat169	Short-Fiber Preform Technology for Automotive Part Production	Dirk Heider (Composites Automation, LLC)	6-91	3.25	3.50	3.50	3.50	**3.44**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat170	Embedded Networked Elements for Resin Visualization and Evaluation (NERVE) System for Intelligent Manufacturing of Multifunctional Composites for Vehicles	Amrita Kumar (Acellent Technologies, Inc.)	6-94	3.17	3.17	2.67	3.17	**3.10**
mat171	Discontinuous Low-Cost Carbon Fiber/Bamboo Fiber Hybrid Intermediates for Lightweighting Vehicle Applications	David Knight (Resource Fiber, LLC)	6-97	3.25	3.25	3.25	3.00	**3.22**
mat172	High-Performance Fiber-Reinforced Vitrimer Composites through Compression Molding	Yinghua Jin (NCO Technologies, LLC)	6-99	3.17	3.00	3.33	2.83	**3.06**
mat173	Self-Sensing Fiber-Reinforced Composites	Christopher Bowland (ORNL)	6-102	3.50	3.50	3.00	3.50	**3.44**
mat174	Carbon-Fiber Technology Facility (CFTF)	Merlin Theodore (ORNL)	6-105	3.17	3.17	3.33	3.17	**3.19**
mat175	Novel Materials for Polymer Composite Engine Blocks	Amit Naskar (ORNL)	6-108	3.00	3.00	2.88	1.50	**2.80**
mat176	Advanced Anticorrosion Coatings on Lightweight Magnesium Alloys by Atmospheric CO2 Plasma Treatment	Gyoung Gug-Jang (ORNL)	6-112	3.50	3.71	3.50	2.50	**3.48**
mat177	Novel Aluminum Matrix Composite for Powertrain Applications	Zhili Feng (ORNL)	6-117	3.00	2.83	3.42	2.25	**2.88**
mat179	Development of High-Temperature Sample Environment for Advanced Alloy Characterization Utilizing High-Speed, Micron-Resolution X-Ray Imaging Techniques	Dileep Singh (ANL)	6-123	3.70	3.50	3.10	3.00	**3.44**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat180	Reducing The Weight of Vehicle Components via Lost-Foam Casting of Ductile and Austempered Ductile Iron	Sarah Jordan (Skuld)	6-127	3.00	3.00	3.50	3.25	**3.09**
mat182	High-Strength Aluminum-Graphene Composite for Powertrain System	Xiao Li, (PNNL)	6-130	3.50	3.63	3.25	3.25	**3.50**
mat183	High-Temperature Coatings for Valve Alloys	Sebastien Dryepondt (ORNL)	6-133	3.50	3.33	3.67	3.00	**3.38**
mat184	Development of Cast, Higher Temperature Austenitic Alloys	Michael P. Brady, Yuki Yamamoto (ORNL)	6-137	3.63	3.50	3.25	3.25	**3.47**
mat185	Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing	Derek Splitter (ORNL)	6-142	3.50	3.70	3.70	3.30	**3.60**
mat186	Modeling of Light-Duty Engines	Charles Finney (ORNL)	6-148	2.75	3.38	3.38	3.13	**3.19**
mat187	Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys	Dongwon Shin (ORNL)	6-152	3.63	3.50	3.38	3.38	**3.50**
mat188	Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys	Amit Shyam (ORNL)	6-155	3.75	3.50	3.25	3.00	**3.47**
mat189	Fundamental Development of Aluminum Alloys for Additive Manufacturing	Alex Plotkowski (ORNL)	6-157	3.33	3.50	3.50	3.33	**3.44**
mat190	Oxidation Resistant Valve Alloys	G. Muralidharan (ORNL)	6-160	3.67	3.67	3.67	3.50	**3.65**
mat191	Overview of Advanced Characterization within the Powertrain Materials Core Program	Tom Watkins (ORNL)	6-163	3.13	2.75	3.00	2.75	**2.88**

Presentation ID	Presentation Title	Principal Investigator (Organization)	Page Number	Approach	Technical Accomplishments	Collaborations	Future Research	Weighted Average
mat192	Fundamentals of Austenitic Alloys via Additive Manufacturing	Sebastien Dryepondt (ORNL)	6-167	3.25	3.50	3.00	3.13	**3.33**
mat193	Higher Temperature Heavy-Duty Piston Alloys	Dean Pierce (ORNL)	6-171	3.50	3.67	3.50	3.33	**3.56**
mat194	Accelerated Design of Alumina-Forming, High Temperature Austenitic Alloys	Dongwon Shin (ORNL)	6-175	3.10	3.30	2.80	3.38	**3.20**
Overall Average				**3.29**	**3.31**	**3.30**	**3.14**	**3.28**

Presentation Number: mat118
Presentation Title: Functionally Designed Ultra-Lightweight Carbon-Fiber Reinforced Thermoplastic Composites Door Assembly
Principal Investigator: Srikanth Pilla (Clemson University)

Presenter

Srikanth Pilla, Clemson University.

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

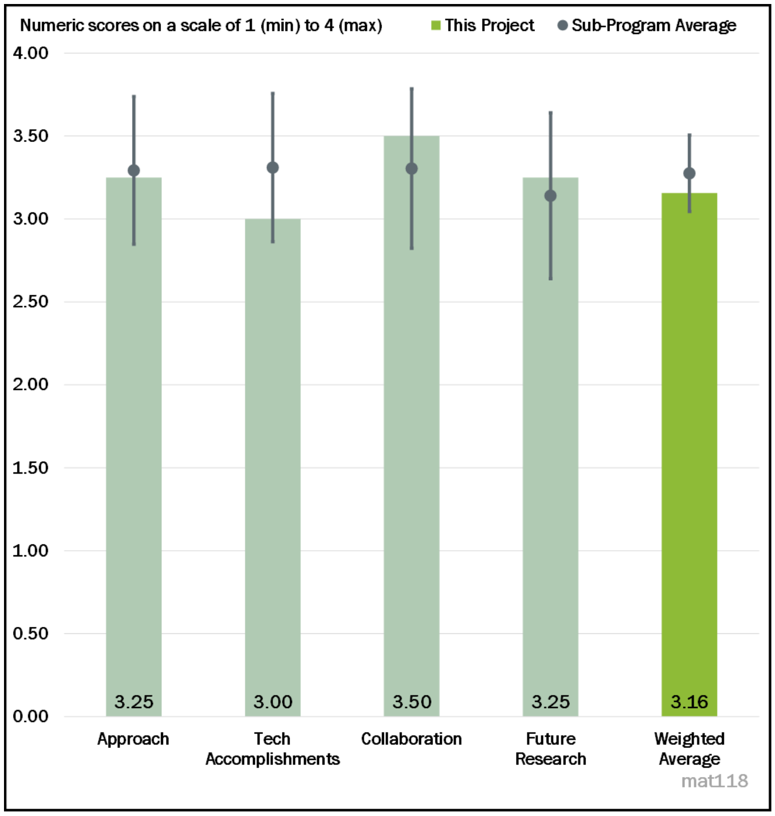

Figure 6-1 - Presentation Number: mat118 Presentation Title: Functionally Designed Ultra-Lightweight Carbon-Fiber Reinforced Thermoplastic Composites Door Assembly Principal Investigator: Srikanth Pilla (Clemson University)

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:

Clemson University is teamed up with the University of Delaware (UD) and Honda North America to design and fabricate ultra-lightweight carbon fiber (CF) reinforced thermoplastic composites for door assembly. The approach is novel, and the results are solid and have met U.S. Department of Energy (DOE) targets.

Reviewer 2:

The approach as detailed by the authors seems adequate.

Reviewer 3:

The research team has made a strong effort to address the primary Vehicle Technologies Office (VTO) goals related to component weight saved and the cost per unit of weight saved. The innovative use of fiber reinforced thermoplastic matrices with lightweight aluminum (Al) and strategic use of steel demonstrate a holistic approach that suggests a strong understanding of material selection and application.

While the use of steel for the intrusion beam is a bit of a sidestep related to the most demanding structural aspect of the door, the projected weight targets met through part consolidation/elimination is applauded.

Material cost of carbon fiber reinforced nylon was a significant concern for the research team, to which the reviewer asked why this choice was made versus alternative technologies that include nylon reaction injection molding (RIM) systems that might mitigate cost through a pre-process to create input materials at a lower total cost. This review would further suggest that industrial carbon fibers used in high volume applications are now significantly lower than the noted $7/lb.

Reviewer 4:
The four-phase approach addresses the major areas of automotive door design. The one shortcoming in the approach was having the material characterization plan based on flat plaque samples that repeatedly have been shown to be optimistic compared to material properties of shaped parts.

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 achieved many milestones with significant progress toward the overall project objective. The team lays out a pathway to mitigating the risks.

Reviewer 2:
The research team is a partial victim of the COVID situation because current conditions on campus and within industry challenge progress. However, this is now into year five and molding tools have not yet become part of the program, which appears to be lagging. Nonetheless, progress on achieving goals related to design and manufacturing feasibility is noteworthy and commended.

While the cost goal has not been met, the research team projects a cost penalty of $5.40/lb of weight saved. It would be worthwhile to challenge the material suppliers—what carbon cost is needed to achieve the $5/lb of weight saved target? Is this design feasible if one projects a carbon fiber cost of $5.50/lb?

Reviewer 3:
The reviewer observed solid progress on the technical accomplishments. However, neither the mass reduction nor the additional cost per pound saved targets were met. The project fell 5% short of the mass reduction at a cost per (insufficient) mass saved that was $0.40 more than the target. The performance from the tests reported was satisfactory to this reviewer.

Reviewer 4:
Good progress has been made in the work. Techno-economic analyses of the final door production and cost seem to be missing, based on results from the authors' work, not on projections. Any supply chain issues have not been mentioned or addressed. The reviewer noted that the woven carbon fiber cloth was obtained from a supplier and inquired about how this is expected to affect final cost of the door. Is this supplier a sole supplier? If so, how might this affect tech-to-market transfer of this technology? The reviewer also noted that there is no word on durability of the carbon fiber laminates over time in component form.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Excellent cooperation between all partners to design, analyze, and soon produce the prototype doors for testing. Solid design and adequate cost model show that the design meeting the first performance targets cannot meet the mass reduction or cost targets.

Reviewer 2:
It appears the research team did a very good job leveraging each member's capabilities. From the material selection process and manufacturing simulations (led by Clemson) to the dynamic structural analysis (University of Delaware) and the door component requirements (Honda North America), the team is well balanced and does not appear to suffer paralysis due to lack of project management and coordination.

Reviewer 3:
Collaborators seem to be well coordinated.

Reviewer 4:
The collaboration has been going well among Clemson University, University of Delaware, and Honda North America. The team consists of scientists and engineers with rich knowledge and required expertise in the cross-cutting areas of design, manufacturing, carbon fiber composites, and mechanical testing.

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

Reviewer 1:
The proposed research makes sense and the previous success opens new possibilities and pathways to further reduce weight and cost.

Reviewer 2:
Future work follows the approach to test the prototype door. This reviewer also requested that the actual mass of each prototype door tested is documented.

Reviewer 3:
The research team appears to have its work cut out for them now. With the door design apparently complete, it is disappointing that work remains on tool and fixture design, but the payoff is in sight with a clear path forward toward composite thermoforming activities and door assembly. There appears to be no reason why this team should be unsuccessful molding and completing the door assembly and testing.

It would be helpful for the researchers to step through the cycle time for primary operations to validate the 20,000-unit annual production rate goal.

Reviewer 4:
Techno-economic analyses based on project results seem to be missing.

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

Reviewer 1:
The ultra-lightweight, carbon fiber-reinforced, thermoplastic composites door assembly that was developed supports overall DOE objectives and should find immediate applications in vehicle structures and other components.

Reviewer 2:
This work is relevant to the overall goal of vehicle lightweighting.

Reviewer 3:
Mass reduction at affordable costs will help reduce fuel consumption and reliance on imported oil.

Reviewer 4:
Yes, the project does support overall objectives for improving energy use in commercial automotive applications. The stated objective to reduce the mass of this automotive component (common to all commercial automobiles) of at least 42% will likely be met because of this research work. Furthermore, DOE's stated cost objective is no more than an incremental cost of $5/lb of weight saved. The research team is projecting a cost penalty that is approximately 8% higher at $5.40 per lb of weight saved. The reviewer opined that the cost basis assumed by the research team is modestly high; given volume projected and the direction of material costs for industrial carbon fiber declining, the accomplishments achieved in the present work are both commendable and support 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 research team appears able to accomplish its stated goal of manufacturing the door components with currently available funds. The creation of such a complex system at funding levels of approximately $6 million is notable. The level of cost share is similarly commendable and demonstrates great confidence in the commercial value of this technology.

Reviewer 2:
Funds seem sufficient to complete this work based on information provided by the authors.

Reviewer 3:
The team leverages resources from Clemson University, University of Delaware, and Honda North America. The project is making progress toward the stated milestones in a timely manner.

Reviewer 4:
Sufficient resources were observed by this reviewer.

Presentation Number: mat122
Presentation Title: Close-Proximity Electromagnetic Carbonization (CPEC)
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 indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

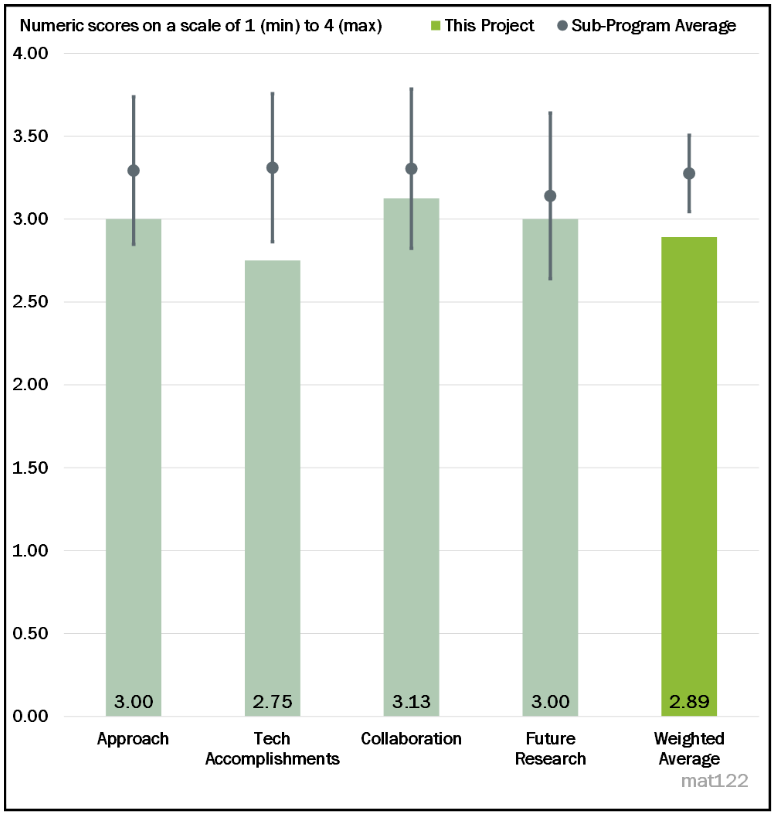

Figure 6-2 - Presentation Number: mat122 Presentation Title: Close-Proximity Electromagnetic Carbonization (CPEC) Principal Investigator: Felix Paulauskas (Oak Ridge National Laboratory)

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 team proposed using a Close Proximity Electromagnetic Carbonization (CPEC) technique to shorten carbonization time and lower carbonization temperature, which is a creative approach. The project started from scratch with many challenges and is progressing toward its overall project goal.

Reviewer 2:

The Oak Ridge National Laboratory (ORNL) research team appears to have created a logical approach and a novel method for addressing the energy intensive and long dwell times for carbon precursor low-temperature carbonization. Developing computational electromagnetic modeling to inform the process is significant and important for overall success. Progress suggests the proposed methods are feasible, but hardware failures imply that this has yet to be fully proven.

Reviewer 3:

This work has been in the making for a couple of years and it is a challenging problem. The approach involves low-temperature carbonization through electromagnetic carbonization. The project team’s overall goal is 50% cost reduction for carbon fiber manufacturing with comparable performance. The team is looking at coupling the energy through electromagnetics to convert precursor during carbonization and minimize energy losses in the furnace. The project team’s designs have evolved through multiple iterations to what is referred to as CPEC-4 with additional configurations added in the current year. While the project team had evidence of carbonization, there was some failure in the cavity. It appears more challenges were encountered in the CPEC-4 in conjunction with the additional configurations.

Reviewer 4:
The project depends on hardware that the team found to be non-conforming to certain phase control specifications; subsequently, this issue has created significant delays. The exact source of the issue is unclear to this reviewer, but reliance on a single piece of equipment points to potential fundamental barriers in deploying the technology and scaling it up in the future.

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 CPEC-4 processing system was ultimately able to show evidence of carbonization, and the project was extended for one year while the hardware issues are sorted out.

Reviewer 2:
The project team designs have evolved through multiple iterations to what is referred to as CPEC-4 with additional configurations added in the current year. While the project team had evidence of carbonization, there was some failure in the cavity. It appears more challenges were encountered in the CPEC-4 in conjunction with the additional configurations. The project team seems to have had a non-conformable generator and is working toward replacing it with a new unit. Results from bringing this on-line will provide more indication of the process' successes, which are not entirely clear, presently. The project team is in the process of evaluating and modeling the new configurations. The number of tows that eventually can be successfully incorporated is unclear at this stage.

Reviewer 3:
The project needs to have new equipment that is not available in the market. The team did theoretical analysis and design of the CPEC equipment, including key components, and has demonstrated the feasibility of carbonizing polyacrylonitrile (PAN) fibers using the electromagnetic method. The reviewer commented that further optimization and scale up proceed.

Reviewer 4:
The hardware setbacks certainly frustrate project progress. However, the processing performed prior to the CPEC-4 cavity failure suggests that process goals are likely to be attained. This reviewer would have indicated more comfortable if the specific cause of the unit failure was identified. There remains some mystery around whether model assumptions, supplier failure to meet performance specifications, or anomalies in the precursor inputs are at fault. This suggests that significant technology gaps remain, which should not be too surprising given the technical readiness level of this important work. The team appears to have a path forward, it has already recovered from the CPEC-4 failure, and that should be recognized.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The 4X Technologies (4X) and ORNL teams are experts in the work and the collaboration is appropriate and very well structured.

Reviewer 2:
The reviewer observed very good collaboration and coordination across the project team. The team leverages the resources at ORNL and 4X.

Reviewer 3:
The collaboration between ORNL and 4X seems appropriate.

Reviewer 4:
This reviewer scored down the collaboration simply because of the apparent differences that have occurred over the supply of equipment to the ORNL research team. When a 2-month period of negotiation is required after a significant equipment failure, this indicates that a program fault may exist. In this case, it clearly has stalled progress.

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

Reviewer 1:
The proposed future research makes sense and lays out a pathway to mitigating the risks in scaling up electromagnetic technique. The reviewer indicated that many tows could be processed, and low-temperature electromagnetic carbonization alone could do entire carbonization without using high-temperature carbonization.

Reviewer 2:
The project is scheduled to close during this fiscal year (FY,) meaning not too much additional proposed work is in order. The project team has indicated that CPEC-4 failure may have been a result of "initial assumptions used in the CEM". It would be reasonable to expect that the team would seek to validate those assumptions or change the assumptions and validate the model. The reviewer wondered if that is possible and what might be done—beyond simply measuring the resulting fiber—to validate the coulombic efficiency (CE) model output and further inform scaled-up equipment designs. Otherwise, the stated work proposed for FY 2020, including the economic analysis, is important for validating the value of this work.

Reviewer 3:
It appears that the new configurations will need tuning. The new (conformable) generator ought to indicate the success or challenges of carbonization and conversion. A reliable and reproduceable carbon yield needs to be demonstrated for commercial viability. Overall, the approach for the next steps seems reasonable.

Reviewer 4:
Future effort hinges on sorting out hardware problems to achieve normal operation of the CPEC-4. The objective of 4 tows (24,000) with 60-second (s) residence time and 250 kilopound per square inch (ksi)/25 million pounds per square inch (Msi) appears to be part of the proposed scope; however, the volume of material promised and how cost is expected to scale with volume is unclear to this reviewer.

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

Reviewer 1:
DOE has stated objectives that include improving the economics of high specific property materials. In this class of materials suitable for industrial and commercial application is carbon fiber. CF manufacturing is very energy intensive, which is a significant cost component. The research work presented under this funding has significant potential to reduce the energy requirement and increase material throughput in a capital-intensive environment. This will drive cost down and expand applications for carbon fiber in transportation resulting in energy savings that align with strategic DOE goals.

Reviewer 2:
Low-cost, high-performance carbon fibers are the key for developing lightweight composite structures. The electromagnetic method holds the promise to decrease conversion cost, which this reviewer indicated is the way to reduce the cost of PAN-based carbon fibers for vehicle applications.

Reviewer 3:
The objective of low-cost carbon fiber is in line with DOE objectives.

Reviewer 4:
Reducing energy of manufacture is a key DOE goal. If successful, this project is in the right direction to address this need.

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

Reviewer 1:
While the program has been challenged by equipment development, the research team has been meeting program milestones and achieving results through no-cost program extensions. The high-risk, high-reward research and development (R&D) appears to be adequately resourced with meaningful results forthcoming.

Reviewer 2:
The team has sufficient resources at ORNL and 4X for the project to achieve its stated milestones. The project is very challenging (starting from scratch in terms of equipment, which is not available in the market).

Reviewer 3:
The team between ORNL and 4X has the appropriate equipment. Some of the updates proposed will further align with resource needs.

Reviewer 4:
The extra year given to the team to sort out issues is appropriate.

Presentation Number: mat124
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles
Principal Investigator: Xiadong Li (University of Virginia)

Presenter

Xiadong Li, University of Virginia

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

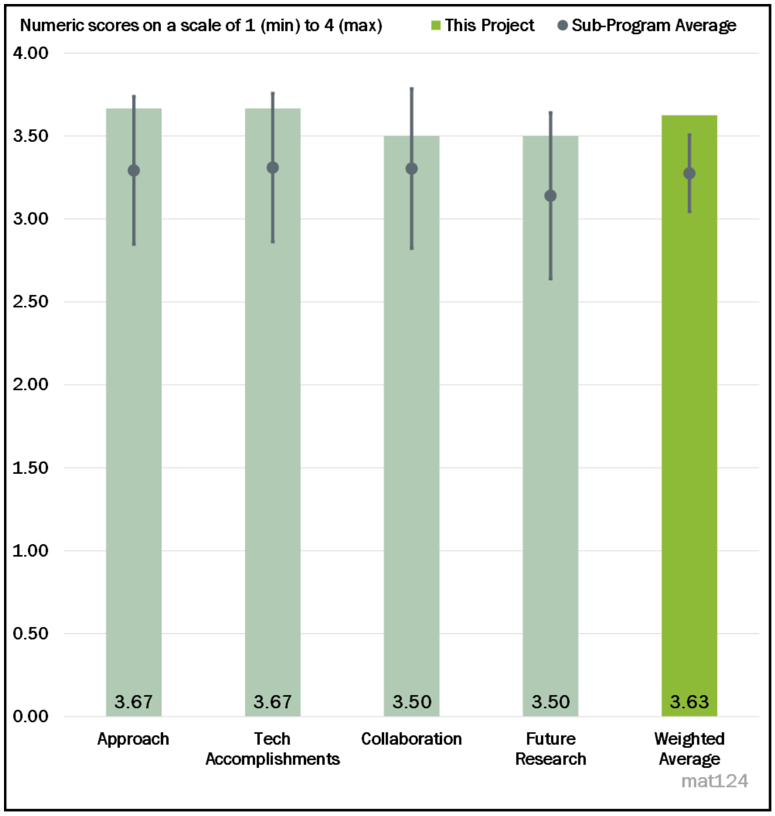

Figure 6-3 - Presentation Number: mat124 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber for Lightweight Vehicles Principal Investigator: Xiadong Li (University of Virginia)

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:

Excellent approach to use integrated computational materials engineering (ICME) to identify cost-effective carbon fiber production.

Reviewer 2:

The project uses ICME tools to guide and optimize the manufacturing process for high-quality and cost-effective carbon fiber. Achieved results prove success of the approach. Precursor processing is very complicated, and the project is able to catch critical elements when applying ICME tools. This is very impressive.

Reviewer 3:

Year 3 work has evolved well from the overall project objective, which is to model conversion of fibers and predict properties. The project team has systematically approached modeling the preoxidation, oxidation, and carbonization and predicted coupled thermal-chemical-mechanical fiber transformation. The Year 3 focus has been to optimize work initiated in Year 2; the project team has shown progress in Ultra-high molecular weight polyethylene (UHMWPE), mesophase pitch, and Nylon 6. While ICME reactive force field (ReaxFF) was more developed for the UHMWPE and Nylon 6, the mesophase pitch was more along the lines of experimental characterization via techniques such as polarized light and Raman spectroscopy. The project team carries on continuum modeling for various pore sizes, geometries, orientations, etc., to refine the predicted properties and core-shell nanostructures.

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 accomplishments on the various precursors, UHMWPE, pitch, various nylons, and the ICME framework. Good summary of accomplishments against DOE targets.

Reviewer 2:
The project has integrated ReaxFF, molecular dynamic (MD) analysis, continuum finite element analysis (FEA), and other computer-aided engineering (CAE) tools to optimize the fiber recipes, maximize properties, reduce conversion time, and reduce precursor and conversion costs. The project has demonstrated technologies and successfully produced high-quality and low-cost carbon fiber in the lab.

Reviewer 3:
Some of the comments made previously apply here. Year 3 work has evolved very well from the overall project objective, which is to model conversion of fibers and predict properties. Technical accomplishments on the ReaxFF modeling of the UHMWPE and PA6, as well as comparisons to the experiments were described by this reviewer as in-depth. The alternate precursors work in these forms is on target per the scope of the work. Progress is demonstrated adequately through performance indicators and metrics. Although the role of the core-shell nanostructures was not fully clear, the work is aligned with the overall scope.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between research organizations are great. Each research partner contributes to project success with VTO's leadership.

Reviewer 2:
The team is very well coordinated. The University of Virginia, Pennsylvania State University, ORNL, Solvay, and Oshkosh are well coordinated in the work and each partner has tangible contributions.

Reviewer 3:
The progress indicates excellent collaboration between the five entities. The reviewer expressed interest in seeing a table of how often there was contact, meetings, or reviews between and among the five entities.

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

Reviewer 1:
The reviewer observed the right next steps to finish the project by September 2020.

Reviewer 2:
The project team's proposed future research is reasonable. The team looks to do the following logical and reasonable tasks for the proposed future research:

- Finalize ICME framework with ReaxFF and MD simulations.
- Complete continuum finite element (FE) model predictions based on experimentally measured pore size and distribution.
- Complete mechanical testing and characterization of pilot-scale alternative fibers to validate ICME predictions.

Reviewer 3:
The planned future research activities are critical for industrial application of the research results. The reviewer would also like to see further development of ICME tools, especially the integration of more detailed process analysis into optimization when considering scalability.

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

Reviewer 1:
DOE is seeking alternate precursors for producing low-cost carbon fiber. This work demonstrates a simulation-based approach backed by excellent experimental work and validation. Hence, it meets DOE goals very well.

Reviewer 2:
Carbon fiber-reinforced polymer composite is one of the most promising materials for vehicle lightweighting. The project has demonstrated technologies and found precursors for high-quality and low-cost carbon fiber. The research will contribute to achieving DOE VTO objectives.

Reviewer 3:
The cost of carbon fiber must be reduced to allow inclusion of carbon fiber-based composites into high-volume automotive products.

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

Reviewer 1:
Sufficient resources were noted by this reviewer.

Reviewer 2:
The team is very well equipped to conduct the simulation and experimental work.

Reviewer 3:
Although the research involved in the project is expensive, the project has been going well, mostly.

Presentation Number: mat125
Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber
Principal Investigator: Jeramie Adams (Western Research Institute)

Presenter

Jeramie Adams, Western Research Institute

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

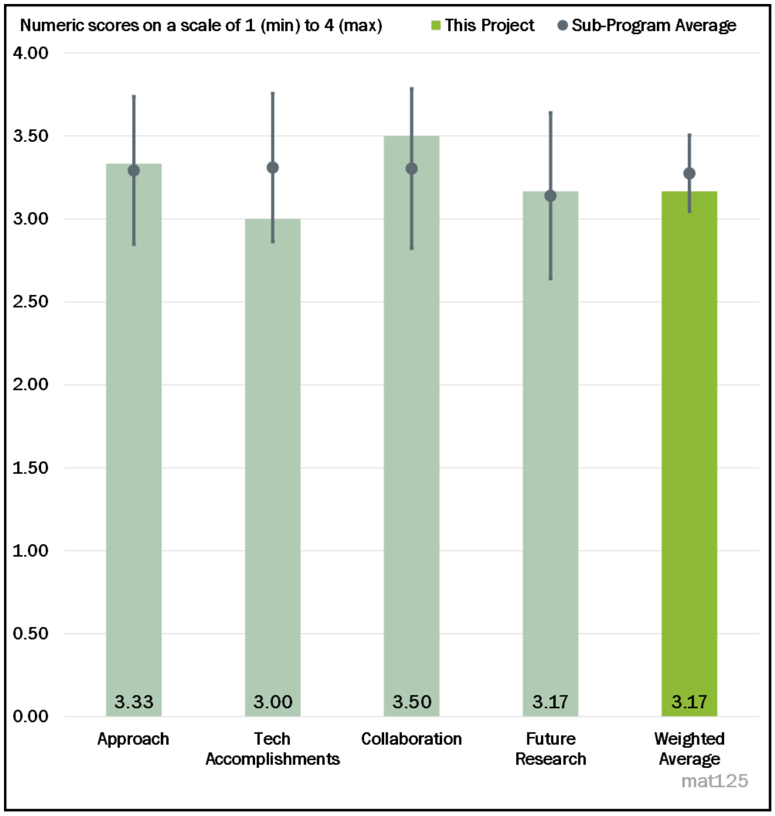

Figure 6-4 - Presentation Number: mat125 Presentation Title: Integrated Computational Materials Engineering (ICME) Predictive Tools for Low-Cost Carbon Fiber Principal Investigator: Jeramie Adams (Western Research Institute)

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:
Good plans and good progress were highlighted by this reviewer.

Reviewer 2:
Western Research Institute (WRI) teamed up with ORNL, Massachusetts Institute of Technology (MIT), Southern Research Institute (SRI), Advanced Carbon Products (ACP), University of Wyoming (UW), Ramaco Carbon, and Solvay Composites to convert biomass, coal, and petroleum oil to carbon fibers. The project team works on removing impurities to get high-quality carbon fibers, yet that may subsequently increase the conversion cost. How predictable are the mechanical properties on batch-to-batch variation due to impurities?

Reviewer 3:
The reviewer is unable to suggest steps to improve the current approach laid out by the authors.

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 made progress toward overall project. The mechanical properties from bio-acrylonitrile (ACN) met the DOE targets. The pitch-derived carbon fibers showed low strain (below DOE target strain).

Reviewer 2:
This reviewer reported the following technical accomplishments and progress:

- Chemical and physical characterization of feedstocks/intermediates/precursors/mesophase/CF
- Production of scaled-up, multi-filament CF from bio-ACN and mesophase coal tar pitch (CTP)
- Production of scaled-up, bio-polyacrylonitrile (PAN) CF that met DOE requirements
- Developed models to go from the molecules to CF properties and machine learning (ML) models.

Reviewer 3:
All accomplishments in the presentation were labeled FY 2019 accomplishments. Being 8-9 months into FY 2020, the reviewer presumed this is a typographical error, but asked for clarification as to whether the work was suspended for 8-9 months.

The reviewer assumed that this is FY 2019/2020 work that has been presented and expressed interest in seeing techno-economic analyses of the fiber cost with this manufacturing process, including any supply chain issues that may either increase or decrease the fiber cost. The reviewer would also like to see validation of the developed model(s) to make the predictions central to the outcomes, including for the atomistic and micro modeling completed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team has put together a strong multidisciplinary team.

Reviewer 2:
This reviewer noted good collaboration among WRI, ORNL, MIT, SRI, ACP, UW, Ramaco Carbon, and Solvay Composites to leverage resources and expertise.

Reviewer 3:
The reviewer was satisfied with the level of collaboration going on 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

Reviewer 1:
The proposed research plans for each aspect of the work are strong and consistent with the overall project objectives.

Reviewer 2:
The proposed future research makes sense and the team lays out pathway to mitigate risks such as impurities and conversion costs. A plan is needed for enhancing the strain of pitch derived carbon fiber.

Reviewer 3:
Techno-economic analyses of the process including supply chain issues, as well as model validation, are required.

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

Reviewer 1:
The project is highly relevant to the production of affordable carbon fiber for vehicle lightweighting.

Reviewer 2:
The project supports the overall DOE objectives. If successful, the low-cost carbon fibers will find immediate applications in lightweight composites.

Reviewer 3:
The objective of low-cost carbon fiber is consistent with 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 resources from WRI, ORNL, MIT, SRI, ACP, UW, Ramaco Carbon, and Solvay Composites are sufficient for the project to achieve the stated milestones.

Reviewer 2:
The reviewer observed sufficient resources.

Reviewer 3:
This reviewer commented that there were no budget figure(s) for FY 2020 and FY 2021.

Presentation Number: mat126
Presentation Title: Room-Temperature Stamping of High-Strength Aluminum Alloys
Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

Presenter

Aashish Rohatgi, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

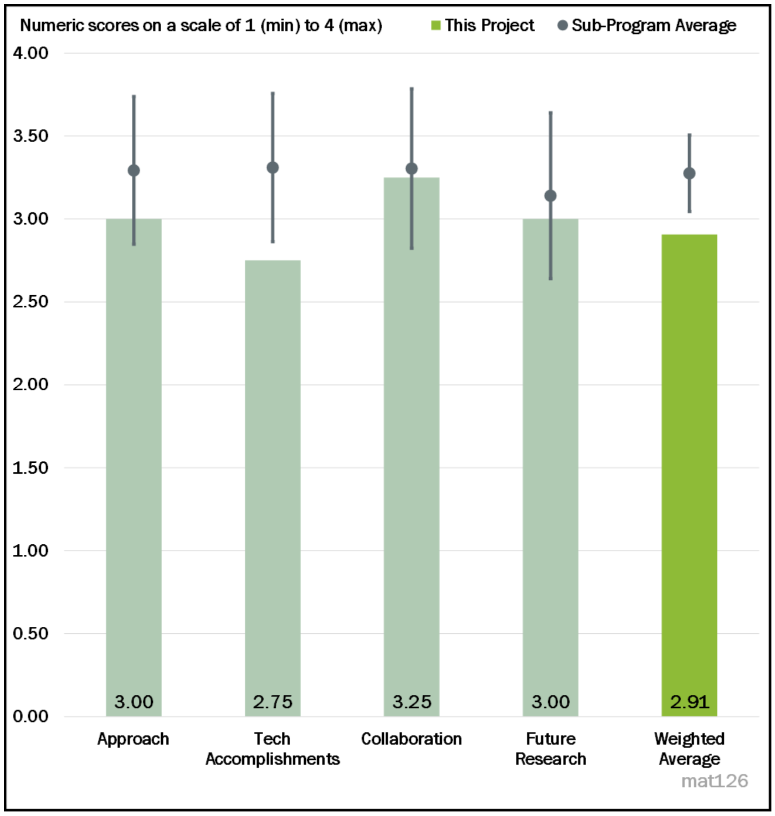

Figure 6-5 - Presentation Number: mat126 Presentation Title: Room-Temperature Stamping of High-Strength Aluminum Alloys Principal Investigator: Aashish Rohatgi (Pacific Northwest National Laboratory)

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 project will evaluate the forming response of a high-strength aluminum alloy at room temperature; this is tested by keeping the tool at room temperature. All aspects of the process are being modeled and experimental trials are included. Further characterization of the material is in progress. Overall, the technical approach is good.

Reviewer 2:

The project team has undertaken a big challenge of room-temperature stamping of a high-strength 7xxx alloy. The approach towards solving the problem is reasonable; namely, formability improvement while retaining strength.

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 modeling of heat treatment including ageing and deformation is completed. Some of the data predicted by modeling was confirmed microstructural evaluation using x-ray and light sources. Experimental verification of the forming process is under progress. Overall, the technical accomplishments are in line with the proposal.

Reviewer 2:
The project team has denoted excessive effort in strength modeling while the formability (or even uniform elongation) aspect has been ignored for modeling. The reviewer hoped the project team can devote some of its remaining time to the latter problem to benefit the broader industry.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer noted a Lightmat project with industry partner (Magna) and described this as a good collaborative effort.

Reviewer 2:
This reviewer observed a DOE laboratory-led project with other labs and at least one Tier 1 supplier involved in the project. Technical input from one OEM is used to define project scope, which will ensure that the outcome will be beneficial for the vehicle manufacturer if it addresses the requirement.

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

Reviewer 1:
The future research plan is good. Formability modeling (even if empirical) will benefit the effort immensely.

Reviewer 2:
No new research is being proposed as it is near completion. It will be useful to have a publication on the current state of understanding on the low-temperature formability of various aluminum alloys as one of the end products.

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

Reviewer 1:
Reducing the cost of metal forming process will enable mass use of the light metal parts. It is known that weight reduction will improve fuel efficiency or vehicle range. Energy efficiency and greenhouse gas (GHG) reduction are DOE focus areas and this project will contribute to those goals directly.

Reviewer 2:
Lightweighting benefits and reduced energy consumption (room temperature forming) support DOE objectives.

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 and the project is nearing completion.

Reviewer 2:
The project is in the last work phase and the delay in work will not impact the total project value. This reviewer added that in-kind contribution from the industry partner is limited.

Presentation Number: mat127
Presentation Title: U.S. Automotive Materials Partnership Low-Cost Magnesium Sheet Component Development and Demonstration Project
Principal Investigator: Randy Gerken (Fiat Chrysler Automotive)

Presenter

Randy Gerken, Fiat Chrysler Automotive

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

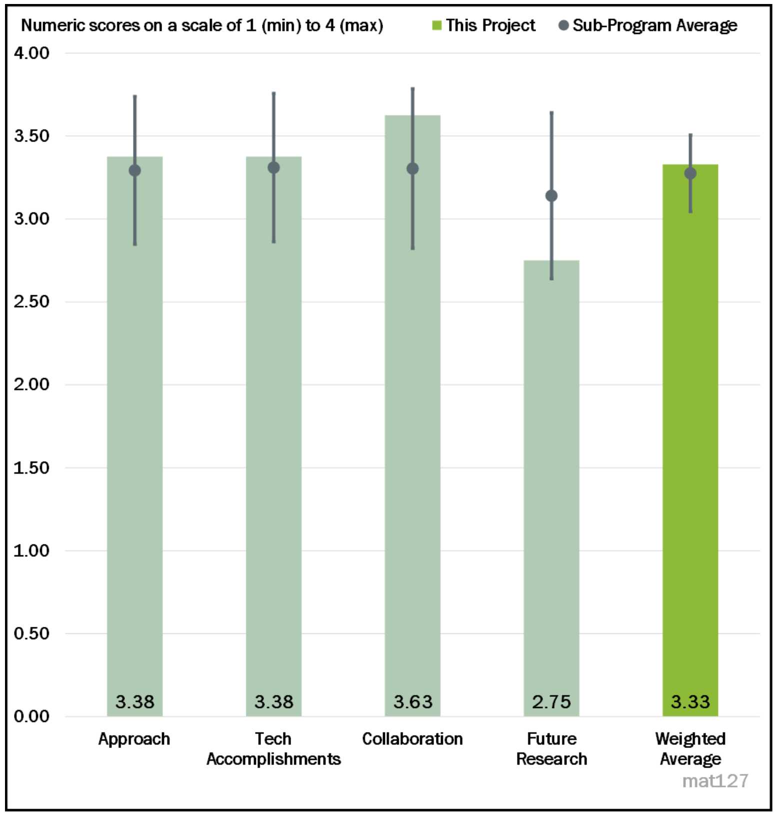

Figure 6-6 - Presentation Number: mat127 Presentation Title: U.S. Automotive Materials Partnership Low-Cost Magnesium Sheet Component Development and Demonstration Project Principal Investigator: Randy Gerken (Fiat Chrysler Automotive)

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:

Very comprehensive program that encompasses material development, modeling, and testing.

Reviewer 2:

The project has well-designed guidelines to develop sheet magnesium (Mg) alloys that can be made by drawing/stamping process for vehicle applications. The use of ICME methodology for alloy development has become popular in recent years. Subsequently, it would be nice for the project to share its experience on the method's effectiveness as related to the alloy development process. The selection of minor additions (zinc [Zn], Al for strength, cerium [Ce], tin [Sn], calcium [Ca] for texture, etc.) to the alloy is reasonable. The effort to correlate texture with formability is important and the right direction to go.

Reviewer 3:

All aspects of Mg sheet performance are being studied including alloy content, texture during forming, joining, and corrosion, which are the major factors influencing Mg sheet use.

The alloy is considerably lean but has many elements including some rare earth elements (REE) at comparatively low level. This is good for the cost but recycling of this sheet at the end of life may be complicated.

Development of modeling capability is useful.

Reviewer 4:

The project appears to be well managed, which is difficult with such a large group. The researchers have identified the main issues—formability and compatibility with downstream processes like paint. Most of the work is aimed at making new alloys, but the demonstration and prototype work will occur with a commercial alloy, which is disappointing. The value of the ICME work may be proven years down the road, but currently, the proof of concept work will be on the commercial alloy, which implies the bulk of the work was unnecessary.

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, good progress was noted by this reviewer. Business decision on material supply influenced the timing, which is understandable under the circumstances. The reviewer also highlighted excellent progress on formability modeling and validation.

Reviewer 2:

The reviewer observed an effort to develop new alloys even though the work is not concentrating on one existing alloy, E-Form Plus. The rationale for this approach to develop new ones is not explained. However, one of the new alloys exhibited high strength after T6 treatment. This may be a good outcome as far as Mg alloys are concerned. This wrought alloy needs to be studied further for other processes, including forging and extrusion.

The coating and corrosion study has established operating procedures and needs to be studied further for larger components; the observation is same for joining techniques.

Reviewer 3:

Progress is being made, but slow work on the alloys and trying to match the E-Form alloy already commercialized seems to be a big drawback. The reviewer observed significant time and effort spent on making new alloys, when something already available is better than what the project team is working on currently. The use of ICME tools is nice and the predictions are matching some of the experimental results, but this all may be for naught. This reviewer would have liked to see more quantitative data on the corrosion testing (scribe creep, undercutting, etc.). Also, how compatible are the paint shop pretreatments with a mixed metal body structure? Is there a maximum amount of Mg, Al, or steel that can be processed through a bath with the new cleaners and pretreatments that were developed? Is the scribe creep performance of Al and steel (cold-rolled steel [CRS] and electrogalvanized [EG]) comparable to today's performance with zinc phosphating (ZnPhos) or zirconium sub-oxide (ZrO_x)? The reviewer asserted the need to see data on that.

Reviewer 4:

One of the major project goals seems to focus on cost (increase over conventional steel-stamped components of no more than $2.50/lb saved), but not much information regarding cost is shown in the report. The reviewer hoped it will be reported in the next stage of research. It is not clear how the crystal-plasticity model is being used to correlate the microstructure to formability of the alloy. The resource needed to pursue that direction is often underestimated.

In the in situ X-ray experiment, the alloy (E-Forming Plus) identified/developed from this project was not used, but two Mg-Sn/Mg-Ca system, which seems to show poor mechanical property. Is there a particular reason not to use E-Forming Plus? Also, the high-energy diffraction microscopy (HEDM) technique is very unique and powerful but has its limitations. Does the specimen have the suitable grain size/microstructure for this technique?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
It appears that there is excellent collaboration among the team. Data are being shared and used by the various team members at different institutions. This looks like a strong suit of the project.

Reviewer 2:
The presenter clearly acknowledged the multiple partners and their efforts during the program. There is an excellent balance between the industry partners, including major original equipment manufacturers (OEMs), suppliers, and university members.

Reviewer 3:
Three OEMs with suppliers, universities, and DOE laboratories are involved in this study, making it easy for dissemination of knowledge. Each participant role is clearly defined, and the presentation highlights each member's progress. Good work.

Reviewer 4:
Team partners are well balanced and cover academia and 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

Reviewer 1:
Generally, the project team has done a good job, but this reviewer questioned the need for all the alloy development if the project teams already has an alloy that works. It seems the project team should have pivoted to something different or deferred some of the research once it had an alloy that met most of the team's goals. It is unclear what the project team will do with the new alloys under development or what will be their advantages.

Reviewer 2:
The budget and future work plan is appropriate. The project is in the final stretch; even though technical tasks are completed, there is no defined path for future production and use. This will be a failure on the project as findings are not used immediately.

Reviewer 3:
It would be helpful to update the cost model to illustrate the cost of the demonstrator door part.

Reviewer 4:
The project indicates "Develop test methods to characterize anisotropy in Mg sheet as current standardized tests were determined to be ineffective" as the remaining barrier. Is there any effort proposed in FY20/FY21 to address this problem?

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

Reviewer 1:
This project support's DOE's lightweighting efforts for automotive and transportation structures. It supports new, innovative materials and their manufacturing to offer additional tools to meet aggressive weight targets meeting cost constraints. The project employs many partners that address many of the downstream requirements (bonding, painting, welding, joining) that are commonly not evaluated on new material development applications.

Reviewer 2:
The reviewer agreed that this is relevant to VTO's objective of developing material/process to advance vehicle-related technology.

Reviewer 3:
Yes, the work does support goals—lighter weight and thus, improved fuel economy.

Reviewer 4:
Magnesium is proven to reduce vehicle weight and can contribute to overall GHG reduction and fuel consumption. Magnesium sheet can be used in many applications, both internal and structural; however, the future process of mass sheet production is not certain.

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

Reviewer 1:
Acknowledging that the project team got an 11-month extension due to some supplier issues, the project appears to have a good team and sufficient resources to complete its task on time.

Reviewer 2:
The reviewer observed a complete plan and sufficient funding during the last year of work, and noted that the project is on no-cost extension.

Reviewer 3:
Project employed the right team members to effectively address bonding, painting, and coating technologies.

Reviewer 4:
The project consists of teams with diverse background and experience.

Presentation Number: mat136
Presentation Title: High-Performance Computing and High-Throughput Characterizations toward Interfaces-by-Design for Dissimilar Materials Joining
Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

Presenter

Xin Sun, Oak Ridge National Laboratory; Ayoub Soulami, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

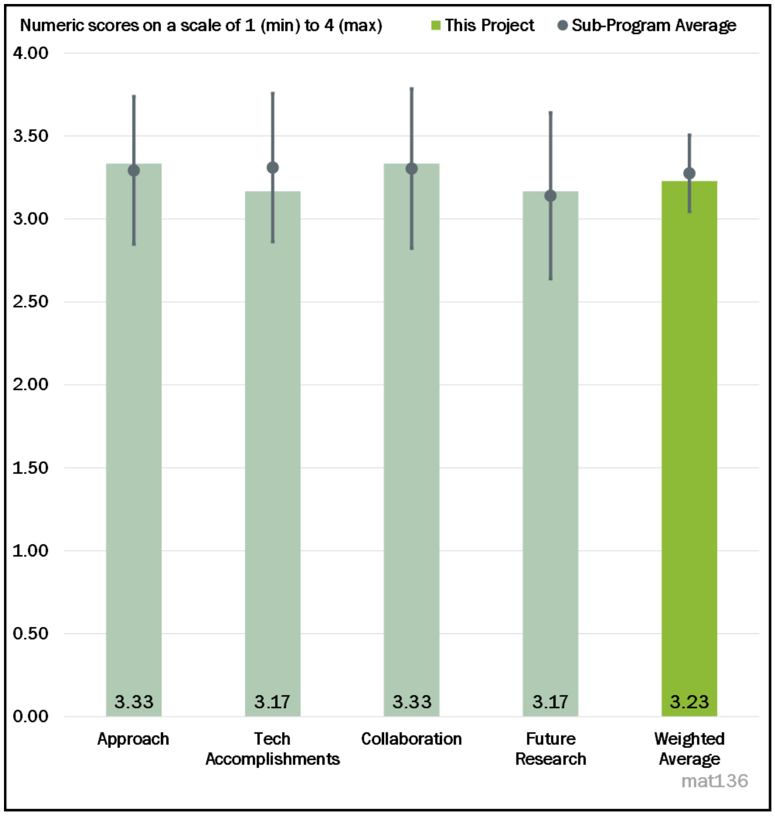

Figure 6-7 - Presentation Number: mat136 Presentation Title: High-Performance Computing and High-Throughput Characterizations toward Interfaces-by-Design for Dissimilar Materials Joining Principal Investigator: Xin Sun (Oak Ridge National Laboratory)

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 design team's approach by the interface is strong.

Reviewer 2:

Although very good work has been done developing tools and approaches on multiple fronts (ultrasonic welding, friction stir welding, adhesive bonding) as exemplified by the content of the presentation, the reviewer opined that this project is extremely broad and suffers from a lack of sufficiency in any given area. For example, the project team has been able predict bond strength/failure modes at the Mg/iron (Fe) interface, but this is after the fact of the experimental work. How can this model now be used to drive the process development work? Great potential is seen in these tools, but they need to be applied to understanding the fundamental problem to drive the experimental work. However, the team has made significant contributions given limited resources and breadth of focus. If there is a step two in this initiative, then a narrower technical focus (or added simulation resources) should be identified to create the critical mass needed to move a given joining technology forward.

Reviewer 3:

This reviewer asked how the work performed at ORNL and Pacific Northwest National Laboratory (PNNL) could be linked. There may exist some similarities between the different processes, and the generated knowledge may be applied across the process at a certain level. For example, the material models could follow the same governing laws under thermomechanical loads for different processes.

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:
Good progress was achieved on the Mg-to-coated steel interface including experimental and computational efforts.

Reviewer 2:
The team accomplished the milestones mentioned. Novelties of the work could be highlighted in the future presentation.

Reviewer 3:
The team has clearly presented the interface by design framework for the Mg/Fe interface applying a diffusion/solidification model for Zn-coated steels and subsequent mechanical properties/fracture based on microstructure. The reviewer highlighted this as a prime example of the first step in interface by design. The inverse FE approach coupled with digital image correlation (DIC) leverages the power of the DIC-generated data. However, it is not clear how this could help understand the effects of surface treatments applied to improve adhesive bonding.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Strong collaboration among the various teams.

Reviewer 2:
The ability to complete an inverse FE approach requires clear communication with the experimental team. The ability to model the Mg/Fe interface microstructure and fracture requires detailed experimental work and close collaboration of the teams. The project results presented clearly demonstrate a close collaboration. However, the true test of collaboration and coordination is when these models are used to direct the experimental work. Looking forward to a continued Phase 2 where the tools developed in this project are applied in this regard.

Reviewer 3:
PNNL and ORNL are working on different processes. Within one process, the simulation and experimental groups collaborate well.

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

Reviewer 1:
Given that the project is expected to be completed by September 2020, the team goals listed on Slide 20 are reasonable and appropriate.

Reviewer 2:
This reviewer reported that proposed future research is contingent on funding levels according to the presenters.

Reviewer 3:
Noting that the project will finish September 2020, the reviewer indicated that future work seems too much to finish in such a short time.

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

Reviewer 1:
Multimaterial joining is a critical technology for DOE.

Reviewer 2:
This project supports lightweighting technologies by joining dissimilar lightweight metals.

Reviewer 3:
This project has developed numerical-based tools that elucidate the fundamental physics ongoing at the interface of dissimilar material joints fabricated with a range of processes. This fundamental understanding can then be applied to improve the joining processes to achieve optimum joint strengths and process robustness, which then are of industry interest to implement multi-material, mass-saving constructions.

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

Reviewer 1:
The team is well prepared with required recourses, including joining process, characterization techniques, and simulation tools.

Reviewer 2:
Appropriate resources are available to complete the work.

Reviewer 3:
The project team has achieved its milestones such as demonstration of the interface by design framework on the Mg/Fe joint and experimental/numerical work on the adhesively bonded joints.

Presentation Number: mat137
Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel
Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Presenter

Zhili Feng, Oak Ridge National Laboratory; Kevin Simmons, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

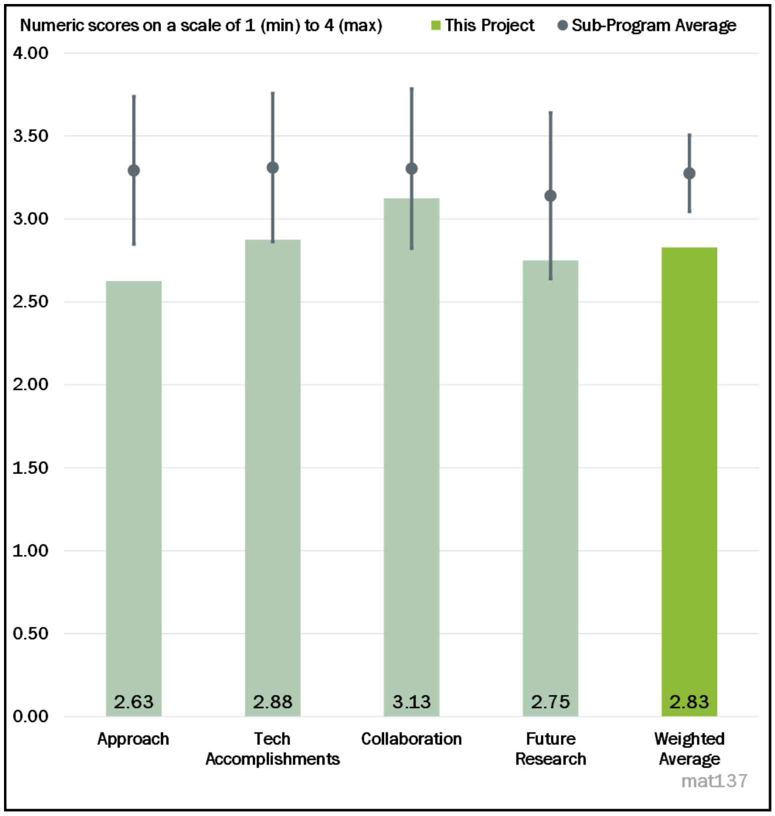

Figure 6-8 - Presentation Number: mat137 Presentation Title: Adhesive Bonding of Carbon-Reinforced Plastic to Advanced High-Strength Steel Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

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 technical approaches are well planned to achieve the milestones. This reviewer asked why the surface compositions are similar in both silane-treated steel and carbon fiber reinforced polymer (CFRP).

Reviewer 2:

The work is in an important area and being carried out in a professional manner. It is not fully clear to the reviewer that this is addressing questions of either fundamental or practical interest. If this is to be practical, it would be advisable to have a larger industry presence and be informed of current design approaches and barriers. If fundamental, greater insight onto the physical chemistry and micromechanics of the adhesive/interface system would be welcome.

Reviewer 3:

There is a significant body of literature showing the benefit of plasma-based silane coatings and laser ablation, which this work reproduces. This project attempts to address too broad of a focus given the resources available. The micro-DIC work at the interface is novel and adds to the current body of knowledge, which is exciting. The reviewer would have liked to see the following: how the interface by design models the change in bond strength with and without the silane surface; how removal of the resin-rich outer layer by plasma or laser ablation affects both surface roughness and chemical bonding; and the relative effects of both. This is an ideal problem to be solved numerically and then validated experimentally.

Reviewer 4:
The main work thrust appears to be surface modification of the CFRP and the steel. This can improve the bond strength potentially, but does not address the main issue of thermal distortion and mismatch in coefficient of thermal expansion (CTE) between the two materials. It is hard to understand how the project team approach will enable these materials to be used together when part distortion is a huge concern. The coupons used by the team are not of sufficient size to understand the residual stresses and strains that will occur when these materials are joined together and subjected to a paint bake.

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 is making solid progress on many fronts including interface development, local chemistry, and mechanics. There is a lack of reporting on published papers or presentations, which represent clear metrics on productivity.

Reviewer 2:
The results are interesting and significant increases in bonding strength are seen. However, there is only one presentation on this work, to which this reviewer suggested that there may be other working papers not included in this review presentation.

Reviewer 3:
The researchers appear to understand surface modification and surface characterization quite well. However, the use of plasma and other surface modification techniques is well understood and practiced in automotive today. This reviewer failed to see anything that is not already used in industry and asked what the team is doing that is new. The plasma as well as the X-ray photoelectron spectroscopy (XPS) and secondary ion mass spectroscopy (SIMS) are all used to assess surfaces for bonding in industry. THE microscopic level DIC (μ DIC) is interesting.

Reviewer 4:
Progress towards the stated project milestones is good. However, Slide 22 (Remaining Challenges and Barriers) is significant; there remains a significant amount of R&D needed in this area to achieve the overall goal of increased use of CFRP/metal joints.

The reviewer expressed confusion by seemingly contradictory statements as to when the work started. Slide 2 states FY 2018 but Slide 33 (Approach) states that research began in FY 2019. A difference of one year is significant in evaluating progress towards overall project goals. Unfortunately, there is little time available in the verbal presentations to address all questions.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The team seems like it is working well together, and this appears to be a project strength.

Reviewer 2:
The project team has very clear deliverables for each lab based on structural competencies at each location. For example, surface modification at ORNL based upon prior work out of that lab.

Reviewer 3:
The collaborations between PNNL, ORNL, and material suppliers are well organized. Did the team compare the adhesives from different suppliers?

Reviewer 4:
Good coordination between PNNL and ORNL. There does seem to be a gap in deep industry participation; they are at least are not called out by individual names and contributions.

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

Reviewer 1:
The remaining challenges and barriers attack well-known issues. Again, fundamental or practical novel contributions are unclear.

Reviewer 2:
The health monitoring and related data analysis may take a longer time than the left time. Also, health monitoring techniques are unclear, and a go/no-go plan is missing for the proposed technique if it will not work.

Reviewer 3:
Referencing Slide 23, the reviewer assumed that "Remaining Future Work" pertains to remaining work the project will attempt to complete before the project ends. However, the third bullet on the "Health monitoring of curing/manufacturing process and structural soundness in service" slide seems to be a task that is well beyond resource limits as defined in this project, which is forecasted to be completed at the end of 2020.

Reviewer 4:
The authors provided almost no insight into how outstanding issues will be addressed. How will the project team manage CTE mismatch? The team talked vaguely about using a lower modulus adhesive, but that technique is well known. The team noted that galvanic corrosion will be a concern, but how will that be addressed? How does the project team plan to isolate the components when the adhesive is poorly dispensed or when geometry allows bridging of the gap between the materials? Carbon is a very strong cathode. What is the proposed method for addressing long-term durability? How does the team ensure that things will stay bonded? What techniques will the team use to assess this? This issue prevents adhesive bonding from being more widely adopted. Undercutting of the adhesive will occur on the steel, especially if galvanic effects occur. The project team needs to do a notably better job of detailing its plan going forward. Currently, it looks like the project team has a lot of issues that will be difficult to address.

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

Reviewer 1:
This project has a strong correlation to overall DOE objectives. Adhesive bonding is the de facto solution for isolating dissimilar materials in a joint; as such, a fundamental understanding of the interface between the substrates and adhesive is critical.

Reviewer 2:
Using adhesives is of clear practical importance for next-generation vehicles. This program squarely addresses those issues.

Reviewer 3:
This project meets DOE objectives by reducing structural weight.

Reviewer 4:
Yes, trying to bond CFRP to steel is worthy to research. However, the reviewer did not see much of a chance that this project would contribute toward this goal as it is currently structured. Surface modification is the

easiest and best understood part of that puzzle. The rest is difficult, and the team may not have the right expertise to do so.

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 with regards to the milestones defined on Slide 4.

Reviewer 2:
The project team seems like it is using its resources well.

Reviewer 3:
The team is well prepared with the resources for the proposed work.

Reviewer 4:
This is a solid program that addresses well-known needs in next-generation automotive design and manufacture. A clear case is not made of exactly how this program fills technical gaps in literature, industrial practice, or knowledge.

Presentation Number: mat138
Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel
Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

Presenter

Piyush Upadhyay, Pacific Northwest National Laboratory; Zhili Fang, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

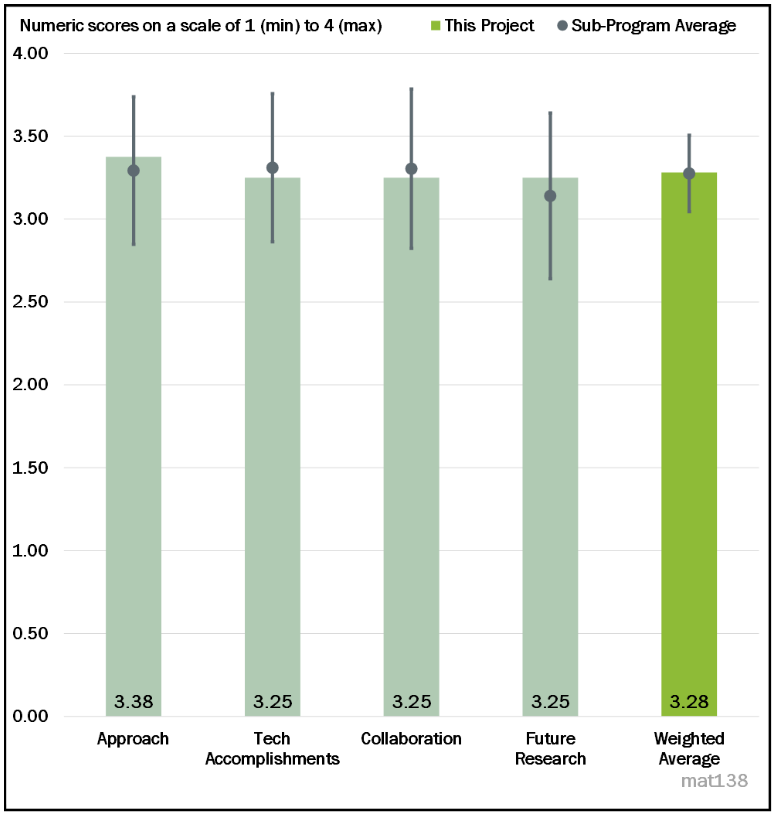

Figure 6-9 - Presentation Number: mat138 Presentation Title: Solid-State Joining of Magnesium Sheet to High-Strength Steel Principal Investigator: Piyush Upadhyay (Pacific Northwest National Laboratory)

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:

This plan represents an excellent coupling of outstanding, important, practical issues of joining advanced metals, novel solid-state processes, advanced structure characterization, and thoughtful mechanical testing—well done.

Reviewer 2:

The project hypothesis is that the joining mechanism is dependent on observations of different elements at the interface and the project team has focused project activities accordingly. The typical process parameters and inherent variability has been acknowledged, but is not the focus of this work, rightly. The application of two, solid-state joining technologies as discussed on Slide 4 provide unique paths to investigate the interface, which is well designed.

Reviewer 3:

The approach is to control the chemistry of the interface to maximize performance of Mg-steel joints.

Reviewer 4:

It seems that the transmission electron microscopy (TEM) function is not fully utilized in identifying structures formed at the bonding interface; only the elemental distributions were presented.

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:
Current results reveal complicated interfacial structures formed at the bonding interface; more in-depth analysis is needed to fully understand the bonding mechanism. The modeling of welding processes provides important information, such as temperature and pressure, which could be further applied in analysis of the generated structures or prediction of the structures with a multiscale modeling approach.

There are eight publications/presentations from this project, which is impressive.

Reviewer 2:
A stated goal is to understand interface chemistry and properties to tailor the joint interface. The project has applied analytical techniques and, in the case of the atom probe tomography, developed a unique approach to understand the interface chemistry and structure. Subsequently, the project has achieved excellent progress. Regarding tailoring the joint interface, the project has achieved a fundamental understanding that enables the team to now address this issue. It is doubtful that the team will be able to make significant impact in this area given the relatively short period remaining in the project.

Reviewer 3:
Important results are being developed in process development, microstructure characterization, and strength testing. Results are all credible and use state-of-the-art techniques. It would be good to cite publications and presentations.

Reviewer 4:
The reviewer observed good progress this cycle, although the issues surrounding bare steel are problematic.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The work planning—ultrasonic welding (USW) at ORNL and friction stir welding (FSW) at PNNL—plays to the strengths of each lab, and characterization and focus on fundamental understanding of the interface drives the two teams to collaborate. This is a very smart approach and enables good collaboration on a common challenge.

Reviewer 2:
The project has a large and well-coordinated team.

Reviewer 3:
The team is strong as part of the broader interface by design effort.

Reviewer 4:
The collaborations were not clearly addressed in the presentation, such as how the two teams from ORNL and PNNL collaborate on different tasks.

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

Reviewer 1:
Plans to investigate joining mechanisms in these difficult materials, effect of loading, and post-weld thermal exposure are all important issues with a clear plan.

Reviewer 2:
Future work aligns well with the project scope. The only concern is if the team has enough time to finish the proposed work, especially during COVID-19.

Reviewer 3:
The four main bullets called out on Slide 16 are appropriate near-term issues that the project should address. However, these items cannot be adequately addressed in the remaining time or with the current level of resources. The reviewer commented that these bulleted items should spawn new projects themselves. For example, the question of resonance is a good one for high performance computing (HPC) if USW is applied to a sub-assembly or other large vehicle structure given the computational needs for that problem statement. The effect of post-weld heat treatment (i.e. paint bake effect) is a very interesting problem looking at aging/residual stress/CTE effects, especially for dissimilar metal joints.

Reviewer 4:
It is unclear how future work will lead to successful bare steel joints.

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

Reviewer 1:
The project supports DOE objectives.

Reviewer 2:
This project clearly addresses issues relevant for dissimilar metal joining, which supports the overall strategy of the right material, in the right form, and in the right application for optimum mass savings potential.

Reviewer 3:
It is essential to understand how advanced and dissimilar metals can be joined. This provides important guidance.

Reviewer 4:
This project supports lightweighting technologies by joining dissimilar lightweight materials.

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

Reviewer 1:
The team is well prepared with the resources for the proposed work.

Reviewer 2:
Project resources should be sufficient to achieve the second milestone listed on Slide 3 by year end.

Reviewer 3:
These are difficult, advanced experiments, and the budget looks appropriate.

Reviewer 4:
Sufficient resources have been allocated to perform the work.

Presentation Number: mat139
Presentation Title: Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium
Principal Investigator: Keerti Kappagantula (Pacific Northwest National Laboratory)

Presenter

Keerti Kappagantula, Pacific Northwest National Laboratory; Yong Chae Lim, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

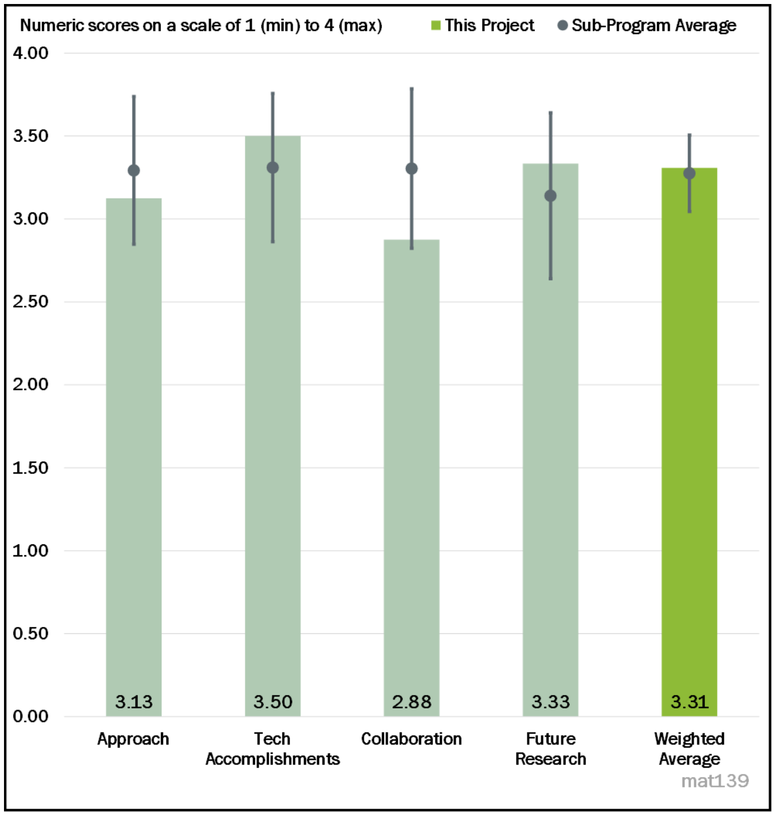

Figure 6-10 - Presentation Number: mat139 Presentation Title: Mechanical Joining of Thermoplastic Carbon-Fiber Reinforced Polymer to Die-Cast Magnesium Principal Investigator: Keerti Kappagantula (Pacific Northwest National Laboratory)

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 project is comprehensive in that it covers process, mechanical and corrosion properties, and has many innovations in joining methods. There is good justification for the methods chosen and they are in line with the state of the art. A slightly broader scope would have been welcomed by this reviewer. Although plan design is useful and consistent with the budget, the covered scope may be a little too broad for the budget. The reviewer asserted that work addresses clearly important areas.

Reviewer 2:

Technical approaches are well planned to achieve the milestones. However, the corrosion mechanisms were not explained; only the effect of corrosion on mechanical strength and failure modes were presented.

Reviewer 3:

The project goal is to develop new Mg/CFRP joining technologies with corrosion performance improved above baseline solutions. Subsequently, the project has taken nascent technologies—friction stir interlocking and friction self-piercing riveting—and applied them to Mg/CFRP joints and evaluated resulting joints with respect to corrosion. This project is higher on the technology readiness level (TRL) and has a corresponding approach compared to some of the other joining core programs. However, the common approach for dissimilar material joints is to apply adhesive at the joint interface and including this variable would have improved comparison of this work to current solutions.

Reviewer 4:
This reviewer noted that the approach did not include a high-volume joining method and added that pop rivet and Teflon-taped fasteners are great control baseline methods.

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 results in terms of quality and quantity were observed by this reviewer. Good innovation has been shown in redesign of the spot joining process and corrosion.

Reviewer 2:
The project has developed satisfactory joint strengths using a range of solutions and addressed the fundamental issue of galvanic corrosion with each of the three methods.

Reviewer 3:
The project plan was executed by PNNL and ORNL as designed.

Reviewer 4:
Significant testing has been done, and more in-depth analysis is needed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer indicated that it is clear the group meets regularly and is well coordinated across both labs and with BASF in the loop.

Reviewer 2:
Each lab leveraged its unique capabilities to develop the joining technologies while the common challenge of Mg/CFRP galvanic corrosion united the team. There appears to be satisfactory collaboration with this project.

Reviewer 3:
Two National Laboratories lead the two tasks based on two joining technologies. It was unclear to this reviewer how these two tasks/teams interact, as well as how knowledge gained from one process can help the other process.

Reviewer 4:
Very little, if any, collaboration took place between ORNL and PNNL. Each group took a different approach and proceeded without interaction and 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

Reviewer 1:
Proposed issues related to friction stir Interlocking and bolting are useful and well justified.

Reviewer 2:
Future work focuses on testing to which the reviewer suggested including more in-depth analysis. Additionally, the technology transfer from lab to industry is unclear.

Reviewer 3:
The tasks as outlined in Slide 18 are appropriate items to be addressed. The reviewer questioned whether sufficient resources remain to adequately address these issues by the forecasted project completion of year-end 2020.

Reviewer 4:
The project has been completed.

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

Reviewer 1:
The project supports a technology gap identified by DOE. Multi-material joining continues to be an enabler for lightweight material use, resulting in fuel reduction and increased energy efficiency associated with electrified vehicles and transportation systems.

Reviewer 2:
This project squarely fits into supporting the overall DOE objective of reduced GHG emissions via increased use of lightweight materials as part of a mixed material strategy.

Reviewer 3:
This project supports lightweighting technologies by joining dissimilar lightweight materials.

Reviewer 4:
Joining ultralight materials is a clear problem with needed innovation, which this project addresses.

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

Reviewer 1:
Resources were sufficient and matched the funding level.

Reviewer 2:
The team is well prepared with the resources for the proposed work.

Reviewer 3:
Resources are justified, but there is a wide scope.

Reviewer 4:
Although the project has made significant advances with available resources, it is questionable whether sufficient project resources remain to adequately address issues by the forecasted project completion of year-end 2020.

Presentation Number: mat142
Presentation Title: Metal-Matrix Composite Brakes Using Titanium Diboride
Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

Presenter

Glenn Grant, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

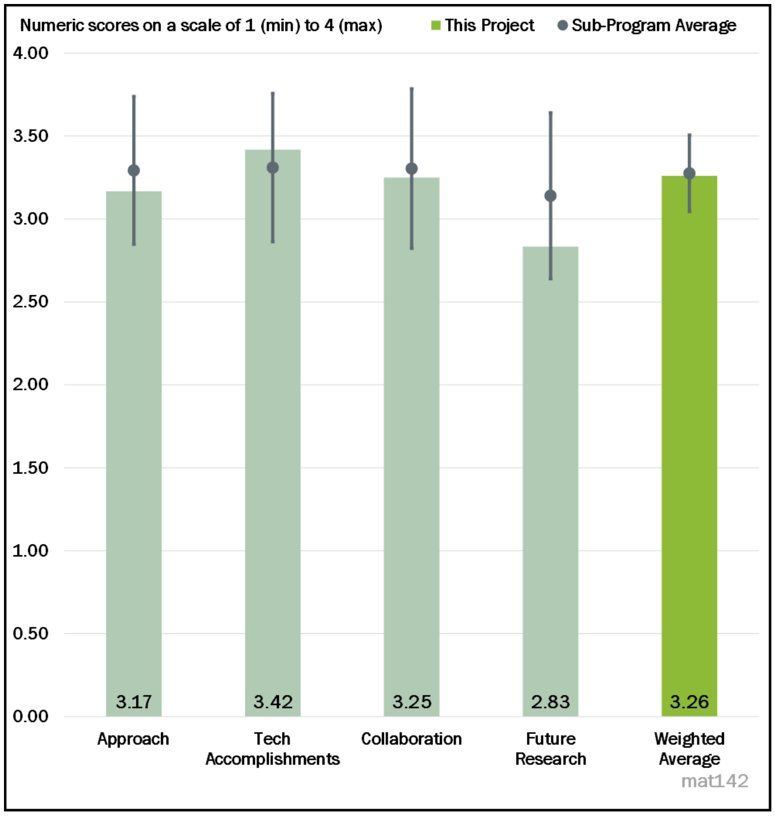

Figure 6-11 - Presentation Number: mat142 Presentation Title: Metal-Matrix Composite Brakes Using Titanium Diboride Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

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 technical approach for using metal matrix composites (MMC) such as titanium boride (TiB_2) and aluminum in various compositions is sound and a good approach for significantly reducing the weight of brake rotors while increasing braking performance. The project was well designed to produce the master alloy and casting alloy to compare to various compositions of metal matrix materials using high-speed techniques to mix the two major components. The reviewer noted a well-conceived approach for using microscopic characterization of the materials for particle homogeneity and porosity before subjecting test samples to industry standard wear tests to characterize the brake rotor component. Cost barriers identified in the overview were not addressed during this project phase. The intent is to do a cost analysis when an OEM partner evaluates the MMC rotors in a full assembly environment.

Reviewer 2:

This reviewer observed a technically-sound approach for making aluminum MMC (with various TiB_2 volume fraction reinforcement) brake rotors replacing cast iron-based rotors. There are challenges associated with aluminum-based MMCs in extreme braking conditions and the authors are aware of that. In addition to lightweighting, there are other benefits such as reduced particulate matter pollution with the Al-MMC based rotors.

Reviewer 3:
Very clear layout of basic approach to fabricate samples was noted by the reviewer. The casting process results show fairly homogenous mixing on the metal matrix and composite. It would be interesting to see more machinability data because this task is required to fabricate the test samples. It is assumed that the casting process is more expensive than cast iron, and the reviewer expected the same to be true for machining. Are these increased costs completely offset by the improved wear life?

In the project team approach, rotors were fabricated from cast plates. Can rotors made from this material with the PNNL casting process be cast near net shape to improve costs by reducing machining?

Excellent details on the review of wear testing, the selected method, and the specific testing profiles.

Will the testing include some severe stopping conditions to evaluate if the rotor can survive or would need replacement after such an event, or worse case fail?

Reviewer 4:
The project's technical approach is adequate for a screening study on the possibility of using TiB_2-Al brake rotors. However, without a technical cost model and analysis of the best potential solution, there can be nothing claimed about addressing the three stated cost barriers to MMC rotors.

Reviewer 5:
The three major barriers listed in this project are all related to the cost (raw material, cost of production). However, these major barriers do not seem to be directly addressed by the proposed effort given that reduced weight and improved performance can also save on vehicle cost.

Reviewer 6:
A simple task was noted by this reviewer; no new technical expertise is being developed. The reviewer commented that a newer material is being used in an older, proven technology of squeeze casting. Validation of this material using common tests is not highly groundbreaking.

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 accomplishments and progress have been outstanding given the level of funding and collaboration between the technical performer and the material producer. The melt trials produced machinable test rotors with very good distribution for the TiB_2 particles within the composite material. Improvements to the brake test stand will ensure better results that will be closer to the technical standard test procedures. The test methodology was well defined and followed typical industry test standards. The parameters for each phase of the test method were well defined and adequate for obtaining the necessary data to screen the test rotors. Test samples were well chosen to compare to baseline test materials and to actual OEM brake rotor configurations. Using a dynamometer test method is more realistic for obtaining results similar to an actual operational environment. This project phase is ending, and the results presented showed very good progress and results that met performance indicators for each of the tasks on the project schedule Gantt chart.

Reviewer 2:
The project team has made excellent progress towards its project goals.

Reviewer 3:
Excellent technical progress on the test stand and test planning. Production of the test samples for the brake wear test is complete for three TiB_2 loadings, and the pads are identified and presumably obtained.

Reviewer 4:
The project is well managed with successfully completed tasks at both industry and DOE lab. Expertise in both organizations has been utilized with good outcome, and minimal challenges have been encountered.

Reviewer 5:
The project seems to show developed MMC material has good performance. It would be better to show a comparison of the developed material with conventional material (e.g., cast iron, other MMC material like silicon carbide [SiC]), in various areas.

It is unclear what type of material characterization was done to correlate the performance with the microstructure of the material. Does the distribution of TiB particle affect the performance?

Reviewer 6:
The reviewer indicated a significant amount of testing and characterization of the tested samples that need to be completed over the next quarter. Hopefully, there is sufficient time to extract all useful information from these tests and make appropriate conclusions. Additionally, the reviewer did not get a sense that this wear testing was being conducted throughout 2019 as the schedule indicated.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer commented that the National Laboratory and industry partner are a good match.

Reviewer 2:
Appears that this project is mainly a PNNL effort outside of the original material procurement. Society of Automotive Engineers (SAE) standards are being closely followed for wear testing and PNNL appears to have all necessary capabilities.

Reviewer 3:
The collaboration is between a DOE National Laboratory and a supplier of raw materials to vehicle manufacturers. The coordination is excellent for producing the baseline test samples and the prototype test samples that compare to OEM component parts. Tasks are appropriately divided for raw material production, casting/machining/testing of rotor samples, and material characterization. There was no indication of direct involvement by an OEM in this project phase. The presenter stated that this phase is for “screening” the new MMC rotors and an OEM is anticipated to be involved in future efforts.

Reviewer 4:
Only two partners and few suppliers of services were reported by this reviewer, who also noted a well-managed project in which expertise was available from the partners for project completion.

Reviewer 5:
Clean approach to division of tasks between the partners.

Reviewer 6:
Arconic and PNNL collaborated on this 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

Reviewer 1:
Very good plan in place to conduct wear testing of the samples to compare performance with different TiB_2 levels and pad materials.

Reviewer 2:
Good project close out is expected given the progress to date.

Reviewer 3:
Proposed future research focuses more on performance evaluation. Additional effort to utilize advanced material characterization techniques and correlate microstructure of material with its performance is key to better understanding this class of material for future improvement.

Reviewer 4:
Proposed future research involves completing the prototype rotors and tribologic characterization of the friction pairs for optimization. The remaining task includes determining the specific wear rate of the rotor materials. This is a logical approach for finishing Phase 1. The presenter did not describe decision points, risks, or risk mitigation for project completion. However, the project is scheduled to be completed within four months; so, it is somewhat late to be considering risks at this point. Success of the research effort is based strictly on past performance.

Reviewer 5:
This reviewer noted the end of the project and no new proposal for future work. The reviewer also highlighted no plan to commercialize the end product.

Reviewer 6:
The proposed future work focuses on technical performance of the rotors. However, the three barriers that all speak about costs are not identified. This reviewer had hoped to see a technical cost model for the manufacturing, machining, and vehicle use stage of the lightweight rotors.

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

Reviewer 1:
The relevance of this project is a significant weight reduction (greater than 50%) of a vehicle component as compared to the DOE 20% goal. If successfully incorporated in a new vehicle by an OEM, the weight savings could also result in a moderate fuel saving, which is also a DOE objective. The presenter also identified an additional environmental impact that is not a stated goal of DOE.

Reviewer 2:
The project supports DOE's lightweighting objective along with reduced particulate matter emissions.

Reviewer 3:
Brake research is clearly relevant to vehicle technology.

Reviewer 4:
Looking at the evolution of transportation systems, materials technologies is at the heart and is a key enabler for all technologies on the horizon.

Reviewer 5:
Braking can be effectively used for regeneration and more stable product will help achieve this goal. Energy conservation will play a role in fuel efficiency and GHG reduction.

Reviewer 6:
Reducing rotating mass has a compounded benefit for fuel economy. It reduces both overall mass that must be moved and the rotational inertia to get the wheels rolling and stopping.

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

Reviewer 1:
Resources are okay for the proposed performance evaluation, but additional resources may be needed for structure characterization.

Reviewer 2:
Resources are sufficient for the level of effort described. The industry cost share was typically significantly more than other DOE-funded research projects, which demonstrates a significant investment and high level of interest by industry for the end product.

Reviewer 3:
Sufficient resources were noted by this reviewer.

Reviewer 4:
Resources are sufficient and project is nearing its end.

Reviewer 5:
Project budget appears sufficient as no flags raised and project is near completion. The reviewer did recall a breakdown of remaining funds.

Reviewer 6:
This reviewer noted the last stage of the project.

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

Presenter

Vlastimil Kunc, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

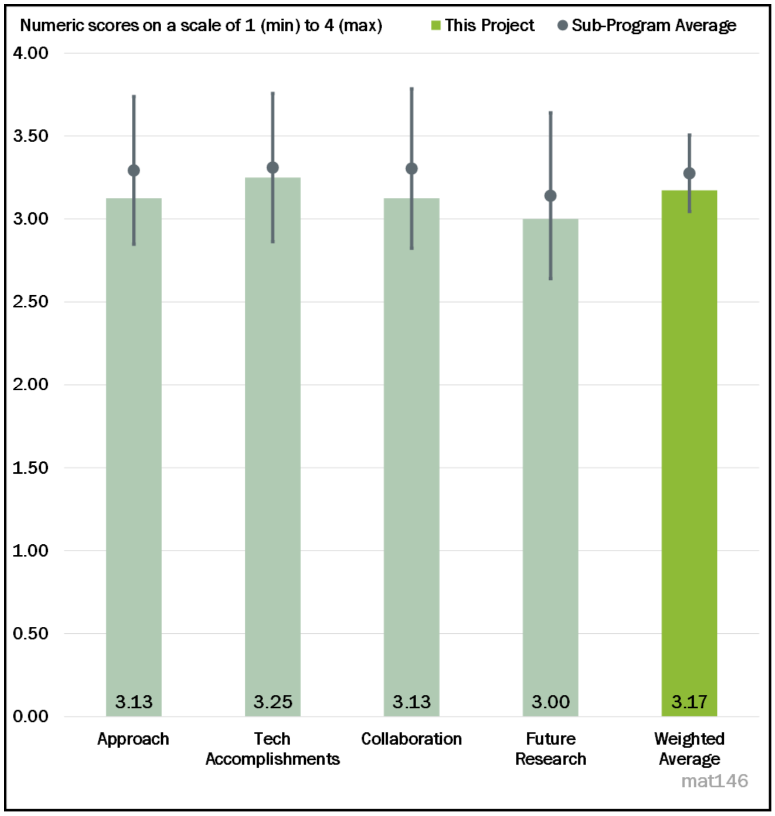

Figure 6-12 - Presentation Number: mat146 Presentation Title: Ultra-Lightweight, Ductile Carbon-Fiber Reinforced Composites Principal Investigator: Vlastimil Kunc (Oak Ridge National Laboratory)

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:

Good approach for this initial study to quantify opportunities and identify challenges.

Reviewer 2:

Using three-dimensional (3-D) printing to manufacture functional material is great approach. Creation of lightweight, high-stiffness microlattice with good damping properties will enable applications of carbon fiber composite in certain special area.

Reviewer 3:

The Research team has pursued a broad range of structural configurations through novel 3-D additive methods and materials. The innovative work is impressive, but the research team could do a better job of spelling out its approach to the research—step 1, step 2, etc. The project team is more intent on showing results and the work performed than describing the starting point, intermediate steps, and the final objective with stated goals. The stated “Overall Objective” does not contain any specifics related to strength, stiffness, deposition rate, or cost goals. It makes it difficult to assess the progress or viability of the technology.

Reviewer 4:

The approach for executing the work seems to be adequate. The reviewer was uncertain about how exhaustive the search was for an optimum, cellular micro-lattice geometry. A more detailed rendering of how this was achieved would be helpful. Perhaps this was presented in prior year(s)?

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 used a multi-material projection microstereolithography (PμSL) system to have successfully printed lightweight cellular test specimens and dementated the printed material's improved damping properties. The impact of density with different amounts of soft phase and size effects of the lattice are also explored.

Reviewer 2:
The work accomplished and progress reported is very impressive. Material fabrication and characterization is complete and shows novel properties compared to conventional materials and methods. This is very well done. The reviewer had only one reservation related to relevance that can only be assessed in the context of cost and scalability, which is not adequately addressed here.

Reviewer 3:
The current technical accomplishments presented go a long way in elucidating intrinsic and structural dampening effects. More needs to be presented on the printing parameters used in manufacturing the lattice structures. The projected economic viability/feasibility (techno-economic analyses) of this method of manufacturing lattice structures for, and in, usable components needs to be addressed.

Reviewer 4:
Good technical progress on the printing and testing. It is not clear how much work was accomplished in this year. How many samples were produced and tested?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Good collaboration though the division of labor and roles and responsibilities are not clearly defined in this presentation.

Reviewer 2:
Given the work accomplished, there can be no doubt that the team has worked effectively. The presentation and reporting do not clearly show the contribution of both partners; however, the work content demonstrates effective program execution.

Reviewer 3:
The project seems to be completed by the PI's team.

Reviewer 4:
There are only two partners in this project. Collaboration seems to be adequate. However, it was mentioned that the Principal Investigator (PI) at Virginia Polytechnic and State University (VT) recently moved to University of California, Los Angeles (UCLA). The presenter did not address whether the move will delay or even impede the work. Did the project move with the Co-PI (Dr. Zheng) to UCLA?

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

Reviewer 1:
Good next steps to identify opportunities and challenges.

Reviewer 2:
The planned research covers a number of new techniques and areas. The reviewer would like to see more comprehensive studies of the new material, especially, their structural strength and durability. Cost assessment of the technology also needs to be considered.

Reviewer 3:
The projected economic viability/feasibility (techno-economic analyses) of this method of developing lattice structures for, and in, production of usable parts/components needs to be addressed.

Reviewer 4:
The proposed research addresses (to some extent) the need to extend scale to "large area CFRP .", which is an important step to create pragmatic materials for structural applications. However, the proposed scale of "> 25 cm x 25 cm" is somewhat underwhelming. Lacking specific reference to build rates, it is difficult to assess the value. Modern automotive operations manufacture full systems at a rate approach one per minute (or faster), it is important to recognize both scale and throughput are critical parameters. Clearly, the future work is pointed at extending material capability, this reviewer remains concerned whether expanding capability is as important as extending scale and rate.

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

Reviewer 1:
If this technology is successfully developed, it will greatly improve the strength of carbon fiber structures. This will promote more extensive use of CF for many structures in vehicles.

Reviewer 2:
The use of 3-D printing technologies to create new material forms (hybrids with novel architectures at small scale) can reveal (at large scale) new material performance that is counter intuitive (e.g., high stiffness with high dampening). This fundamental research is an important building block for development of future systems that will exploit this novel materials approach. To the extent that the methods revealed by this program are scalable to support vehicle manufacturing, the combination of high specific properties and desirable ductility and damping characteristics are important goals of the DOE for lightweighting of vehicle systems.

Reviewer 3:
Carbon fiber composite with improved damping and other properties will enable wider usage of carbon fiber composite and lead to light weight of vehicles.

Reviewer 4:
Tailored materials should reduce vehicle weight and improve performance.

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

Reviewer 1:
The project goes well and is achieving its objectives.

Reviewer 2:
Sufficient funding and resources for this early work.

Reviewer 3:
This team has created significant value in terms of results for the overall program cost. This is notable and commended by this reviewer. Good work with novel outcomes. Please address the feasibility of scaling and address the technology gaps that exist so we can better assess the future funding needs to apply this work in real applications.

Reviewer 4:

This reviewer assumed the budget was sufficient. Authors did not present enough information to ascertain that this was the case. The little information presented might suggest that funding will not be adequate. Total budget seems to be about $1,000,000. Project duration as stated by the author is 50 months (October 2018 to December 2022). 40% of the work has been done, but the amount of money spent was not stated. However, a full 46% of the budget is slated to be spent in FY 2020.

Presentation Number: mat147
Presentation Title: Continuous-Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression Forming Process
Principal Investigator: Philip Taynton (Mallinda, Inc.)

Presenter

Philip Taynton, Mallinda, Inc.

Reviewer Sample Size

A total of zero reviewers evaluated this project.

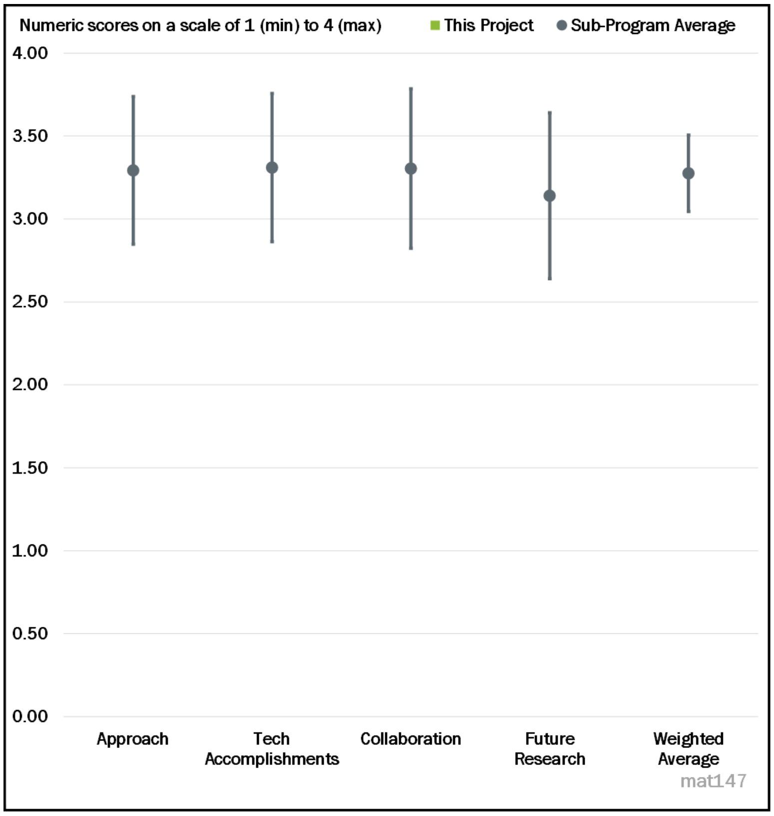

Figure 6-13 - Presentation Number: mat147 Presentation Title: Continuous-Fiber, Malleable Thermoset Composites with Sub-1-Minute Dwell Times: Validation of Impact Performance and Evaluation of the Efficacy of the Compression Forming Process Principal

Project Relevance and Resources

No responses were received in this section.

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

No responses were received in this section.

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

No responses were received in this section.

Question 3: Collaboration and Coordination Across Project Team.

No responses were received in this section.

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

No responses were received in this section.

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

No responses were received in this section.

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

No responses were received in this section.

Presentation Number: mat149
Presentation Title: Non-Rare Earth Magnesium Bumper Beams
Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

Presenter

Scott Whalen, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

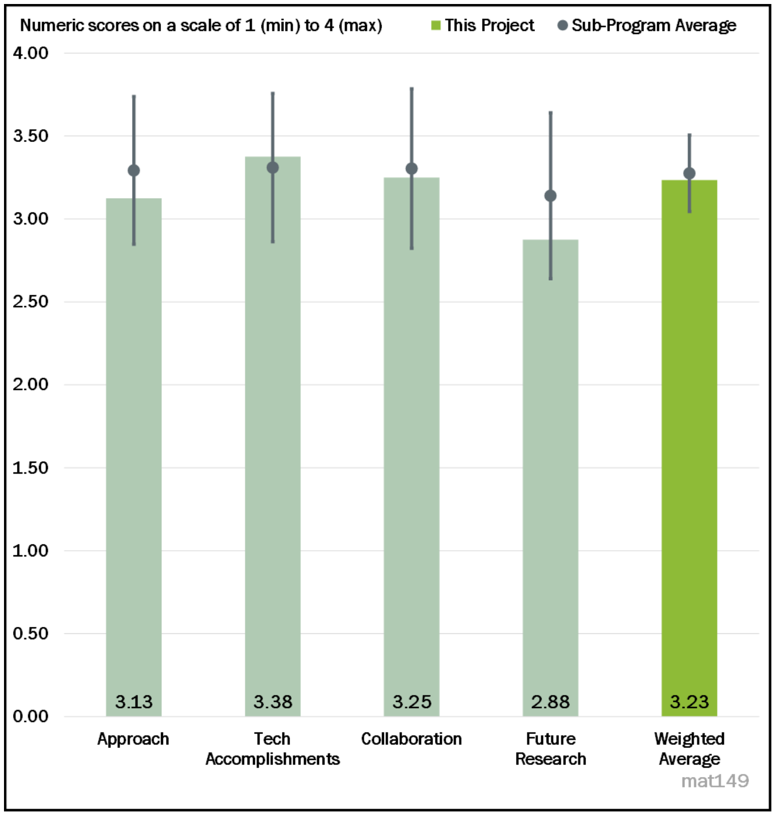

Figure 6-14 - Presentation Number: mat149 Presentation Title: Non-Rare Earth Magnesium Bumper Beams Principal Investigator: Scott Whalen (Pacific Northwest National Laboratory)

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 project addressed fabrication and evaluation of A6063 alloy extrusions using shear assisted processing and extrusion (ShAPE). This is a project with a modified objective from last year; the aluminum task is added and made as first priority. Additionally, the reviewer reported the following experiments: using virgin feedstock followed by recycled scrap; moving from solid to hollow cylinders and then non-circular shapes, which is very progressive; and using magnesium alloy. This will give enough information on the process viability.

Reviewer 2:

The project applies ShAPE processing developed at PNNL to fabricate non-RW Mg alloy bumper beams. The scope has been modified to include extrusion of Aluminum scrap to make ductile Al alloys in the 6xxx family. The approach in this effort is reasonable in all aspects.

Reviewer 3:

The project approach contributes to overcoming most barriers related to producing non-rare earth Mg bumper beams and does so in a logical progression. This includes the addition in June 2019 of more commercially available and readily extrudable AA6063 to increase commercial interest and prove the process before proceeding to the more difficult ZK60 extrusion. However, the project focus is lacking slightly in the omission of typical Al bumper alloys such as AA6061, 6083, or 7xxx alloy. While this project has achieved T6 properties from a T5 heat treatment, those properties are still substantially lower than a conventional higher strength bumper beam grade alloy. There may also be a significant risk to the program in shifting from circular AA6063 extrusions to non-circular ZK60 extrusions without investigating non-circular AA6063 before ZK60.

Reviewer 4:
The approach steadily builds on successively more difficult technical barriers to prove the process at this pilot scale. However, there is no technical cost modeling to build a business case for a successful result.

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 milestones have been reached and technical accomplishments towards overall project goals are good.

Reviewer 2:
The tooling improvements have been excellent! Great results. This reviewer had hoped to see the quantities and “run at rate” information to assess if this was a lab or prototype scale accomplishment.

Reviewer 3:
Technical accomplishments so far seem to be very well aligned with supporting the stated project approach. This reviewer highlighted very good results on AA6063 properties and excellent improvement in surface results, extrusion force, and motor torque from modified tooling, although the machine limitations prevent the ability to evaluate the process at commercially acceptable extrusion rates. The presenter suggested that wide data spread on elongation results may be explained by gripping issues in test cell. Additional testing should be conducted to verify if this is the case. It will be worthwhile in future work to evaluate dimensional accuracy and consistency of extrusion profiles, especially on non-circular profiles.

Reviewer 4:
The project team completed the extrusion of a virgin alloy. Although the selection of 6063 is not justified because it is not normally used for auto applications, 6061 is). Also, this operation may be slower than existing operation. Advantages need to be clarified.

The claim of improved T5 properties needs to be qualified. When extruded from 450C, it could have undergone a quench operation when exiting the punch, thus making it more or less a T4 condition. Subsequent T5 made it close to T6. The reviewer asserted that micro studies are needed to confirm the improved properties; and wide scatter in the properties, including yield strength (YS), needs to be evaluated. Normally, YS will not show much difference with micro defects.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This reviewer observed excellent collaboration to produce these results.

Reviewer 2:
This is a LightMat project with collaboration with Magma. Excellent collaboration with the industry partner is noted.

Reviewer 3:
Only a tier one supplier is involved; partner contribution is significant with help on design and fabrication of tools.

Reviewer 4:
Well-coordinated collaboration that seems to utilize the complementary strengths of the lab and industry partner efficiently. While there are only two collaborators working on the project, these two should be

sufficient for the near term, although ultimately, adding a commercial extruder could help expedite process commercialization.

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

Reviewer 1:
The project is on track to meet the (modified) goals that have been set forth.

Reviewer 2:
While the overall approach is good, the evaluation of AA6063 in a non-circular profile would seem to be a logical addition to the plan prior to going straight to non-circular profile ZK60, which is more difficult to extrude than the AA6063. Additionally, modification of tooling (if feasible) to accommodate higher extrusion rates and addition of a commercial extruder would help increase likelihood of using the process in production.

Reviewer 3:
Work on 6063 with scrap as an input is continuing. However, this is more of a commercial application than automotive. The trial may provide technical information, but an alloy relevant to auto needs to be selected.

Reviewer 4:
The proposed future work will lead to a "proof-of-concept" technical assessment. Including a technical cost model would strengthen the project.

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

Reviewer 1:
The project supports DOE objectives by focusing efforts at developing a process to produce high strength lightweight Mg alloy bumper beams (and potentially other extruded structural components) cost effectively. While also evaluating the new ShAPE extrusion process on more readily available and lower cost AA6063 to meet the industry partners nearer term needs.

Reviewer 2:
Cost reduction in wrought light alloys is an enabler for wider use in vehicles. This will in turn help more light weighting.

Reviewer 3:
Project supports lightweighting goals through the development of non-RE Mg alloys and aluminum alloy extrusions from scrap.

Reviewer 4:
Aluminum and magnesium performance as well as the likely costs of producing linear profiles would probably reduce vehicle mass and, therefore, improve 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 project budget seems appropriate for the length and complexity of the program. The project has already progressed to the point of producing improved quality, non-circular, thin-wall AA6063 extrusions while using approximately 50% of the budget. Subsequently, it would appear that another 50% of the budget should be sufficient to finish the project and hopefully, to accommodate any surprise issues that arise.

Reviewer 2:
Sufficient resources were noted by the reviewer.

Reviewer 3:
Resources are sufficient.

Reviewer 4:
No comments were indicated by this reviewer.

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)

Presenter

Adam Powell, Worcester Polytechnic Institute

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

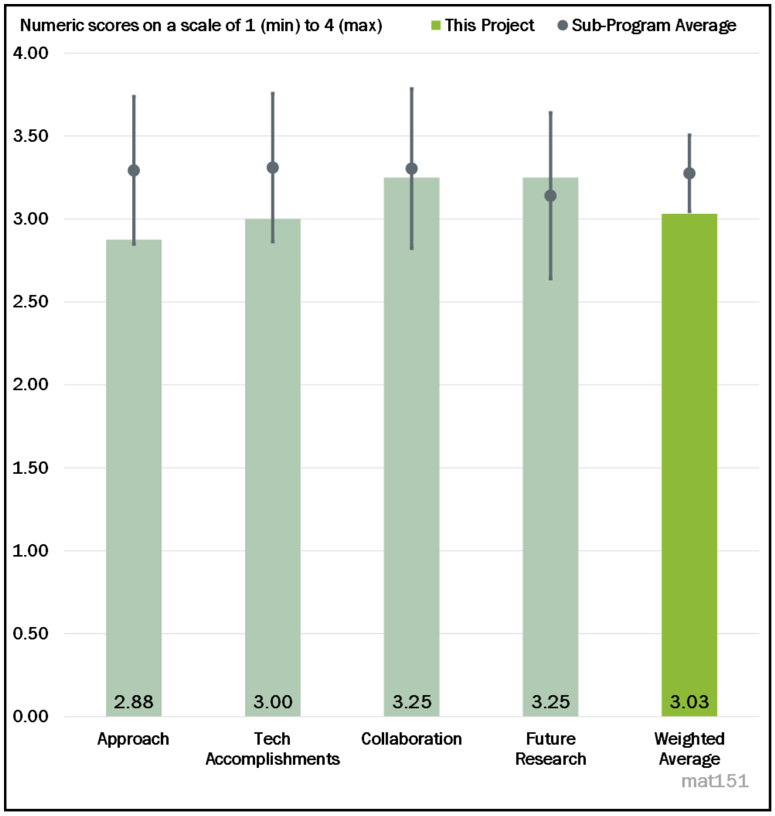

Figure 6-15 - Presentation Number: mat151 Presentation Title: Phase-Field Modeling of Corrosion for Design of Next-Generation Magnesium-Aluminum Vehicle Joints Principal Investigator: Adam Powell (Worcester Polytechnic Institute)

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 of developing and validating a model of microgalvanic corrosion and mechanical failure based on joint microstructure is well-designed and feasible. It also addresses a critical need in providing enhanced understanding and prediction of multi-material joint corrosion and fracture.

Reviewer 2:

Overall approach appears sound. Using Mg/Al diffusion couple to validate the diffusion model is a good idea. However, it was unclear to the reviewer how the corrosion model referenced on Slide 13 has been validated for the Ti-Mg-Cl system. The reviewer saw plots of simulation results but did not see how this is validated against experimental measurements.

Additionally, this reviewer asked the following questions:

- How will the phase field modeling address the difference in grain size between the stir zone and base materials? It is known that the refined friction stir zone will have a lower corrosion rate.
- Will the team address the difference in strengths between the friction stir weld and base material as crack propagation typically follows along this interface?

Reviewer 3:
The effect of the identified intermetallic compounds on corrosion and fracture have not been adequately addressed. The reviewer presumed this will be addressed in the future as part of this work.

The reviewer found the model described on Slide 14 to be rather simplistic. The reviewer assumed that this is an initial simplified model. The model as is does not take into account the compositional and metallurgical variability across the fusion line and into the pure material on both sides of the fusion line. Is FSW being used as a surrogate for diffusion bonding? If so, variability also occurs in diffusion bonding, and the previous comment about compositional and metallurgical variability across the weld fusion line and adjacent metal would still apply.

Reviewer 4:
Overall, the approach seems logical but is not defined well enough to ascertain how well it is addressing the technical barriers. Tasks are unclearly defined and metrics for evaluating corrosion at joints are not well defined 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:
The team has accomplished good progress towards achieving its ultimate goals given a roughly 1/3 burn rate by validating the model based upon Mg/Al diffusion joints with clear microscopic analysis which has been modeled with good correlation (Slide 9). It is clear that the project should continue with the triangular friction stir weld tool.

Reviewer 2:
The reviewer observed good progress made. There is still limited understanding per the data presented about what the effect of the intermetallic compounds is on corrosion and degradation. Additionally, the corrosion model still requires some work.

Reviewer 3:
The technical accomplishments to date are encouraging and generally on-time. The two-dimensional (2-D) model is still limited to simple Al-Mg-H2O ternary system and must be expanded to the Mg-Al-H-O quaternary system to address corrosion product formation.

With the understanding that there was a limited amount of time to present a large body of work, it was hard to dig into technical details. It was interesting to see that the final voltage min/max are located near the edge of the 2-D simulation on Slide 14. Does the position of the min/max voltage change with time (or simulation cell size); if so, how?

Reviewer 4:
Technical accomplishments seem to support the stated approach for the most part. However, a go/no-go for Budget Period 1 was to predict corrosion pit depth within +/- 2X while nothing in the "accomplishments and progress" section of the report even mentions pit depth with respect to testing or prediction. Furthermore, there does not seem to be anything in the presentation comparing predicted corrosion results to test results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Slide 4 provides an excellent overview of the various tasks, timing, and which partner is delivering what. It is clearly based upon each partner's competency and the work to date clearly highlights the collaboration between partners without which they would not be able to achieve the results presented here.

Reviewer 2:
Collaboration within the team seem to be good and effective.

Reviewer 3:
Collaboration among partners seems to be well instituted and effective.

Reviewer 4:
Overall, it appears that collaborative partners have complementary strengths. However, their roles are not defined as clearly as they should be. For example, PNNL is responsible for Task 1, but Task 4 is not defined anywhere in the presentation.

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

Reviewer 1:
The proposed future work and associated deliverables are appropriate for the program.

Reviewer 2:
The project presents a well-thought approach to the problems of corrosion at this point. There is a path forward that has been identified and the tasks outlined in Slide 4 support this path. One concern the reviewer had was the potential for the difference in microstructure/properties of the stir zone versus base materials to affect not only the assumed corrosion rates, but also the strength/fracture of the joints.

Reviewer 3:
This reviewer remarked that there was no mention of elucidation of effect of intermetallic compounds on corrosion and degradation. Additionally, there was no mention of any testing to better understand materials fracture. It appears fracture is going to be modeled without gathering of test data. If so, this is not ideal.

It would have been nice to better understand the effect of the weld microstructure and chemical variability on corrosion and fracture, and how these may be represented in the final model. Do the authors consider this to be part of the scope of this work?

Reviewer 4:
Although details are lacking, future work seems well planned to support the project objectives. Metrics seem to be lacking for determining the capability of the model to predict physical corrosion.

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

Reviewer 1:
This program addresses multi-material joint corrosion and fracture, which are critical parts of implementing multi-material systems.

Reviewer 2:
The project supports the DOE objectives of multi-material joining capability, galvanic corrosion performance, and predictive modeling of galvanic corrosion of multi-material Mg-Al joints.

Reviewer 3:
This project falls squarely in greenhouse gas emission reduction via increased use of lightweight materials in dissimilar material joints. Strength reduction via corrosion is a significant roadblock to broad application of dissimilar material joints.

Reviewer 4:
Better understanding of weld practice/methodology on microstructure, as well as prediction of weld performance of lightweight alloys support the overall DOE objectives of vehicle lightweighting. Subsequently, this contributes to achieving DOE fuel efficiency goals.

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 achieve the work outlined in this project.

Reviewer 2:
The resources seem sufficient. Per the author's own estimates, 33% of the work has been completed against 34% of the budget spent.

Reviewer 3:
This program's resources seem sufficient to enable completion of partner tasks and a successful team as a whole.

Reviewer 4:
Current burn rate indicates the budget expenditures seem to match the timing and accomplishments (each at about one-third of completion) pretty well.

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)

Presenter

Roozbeh Dargazany, Michigan State University

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

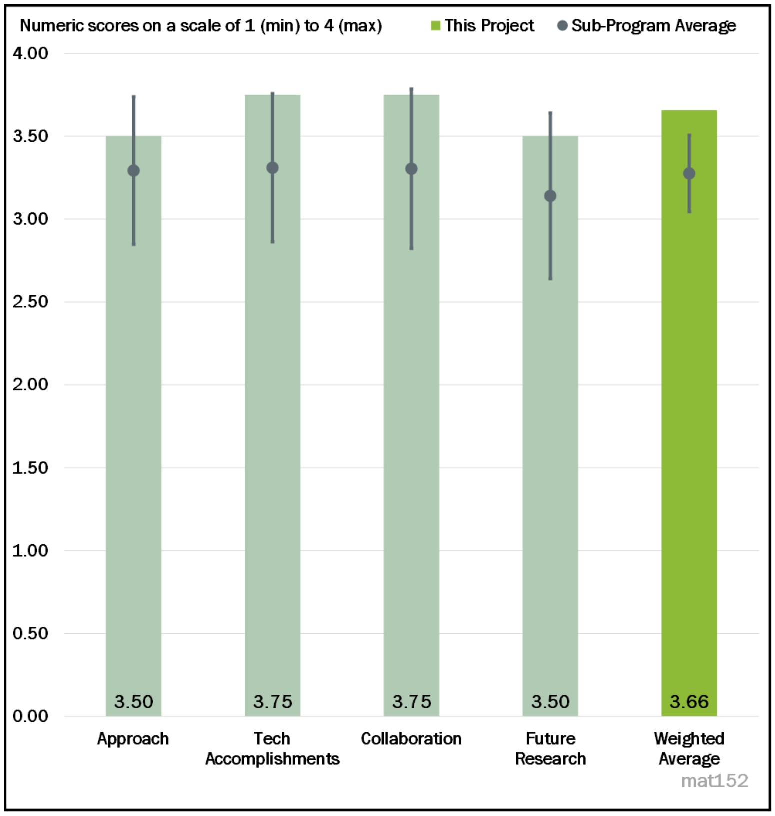

Figure 6-16 - Presentation Number: mat152 Presentation Title: A Hybrid Physics-Based, Data-Driven Approach to Model Damage Accumulation in Corrosion of Polymeric Adhesives Principal Investigator: Roozbeh Dargazany (Michigan State University)

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 excellent and well designed.

Reviewer 2:
For modeling and computational methods, the project is well designed, and the tools used make the expected results are feasible. The modeling approach is excellent for deriving the various models needed and validation with good experimental results for corrosive effects from thermo-oxidation, photo-oxidation, hydrolysis, and hygro-thermal. The approach used for investigating and modeling aging mechanisms is related very well with the critical components that comprise an automobile. The project approach addresses technical barriers for the lack of constitutive modeling capabilities to predict corrosive effects and predictive modeling tools that are validated and have a prediction error of less than 10%. The approach does not directly address the technical barriers for a reliable joining technology for dissimilar materials and cost-effective tests for evaluation of corrosion. However, if the models are successful at predicting the corrosion mechanisms, then they will contribute to later development of reliable joining technologies and cost-effective tests. The conceptual approach for the theoretical model is well planned and supported with sound mathematical development of the parameters needed for a successful predictive model. One overall objective for a theoretical model to describe damage accumulation in constitutive behavior relative to five failure mechanisms is significant to a technical approach that will allow successful prediction of corrosion behavior. The milestone chart demonstrated a well-planned approach with partner participation from the initial development of a theoretical platform through

identification of damage mechanisms and failure characterization to the end goal of software predictions and model validation using test samples exposed to a combination of corrosion mechanisms. The modeling approach is well coupled with the selection of materials and criteria needed for experimentation to obtain data for validating the models. The proposal to include a physics-informed cluster of super-simplified neural network engines is a novel addition to the end of the modeling effort.

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:
Very good progress has been made.

Reviewer 2:
The technical accomplishments achieved at the current stage of research are sharply focused on the critical barriers that challenge the development of predictive models and address many aspects of material failures due to corrosive effects. The performance indicators identified in the milestone chart have been met or are in progress with indications that all will be met once laboratory experimentation resumes. Observations from the experiments were significant to identify the symptoms and challenges associated with the data needed to populate the theoretical model. For example, chemical anomalies that occur between adhesives and two opposite effects for the same damage mechanism, such as both hardening and softening, or like effects from thermo- and photo-oxidative mechanisms. The mathematical modeling was well representative of the experimental results and technical challenges were identified throughout the project.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team includes academia, material manufacturers, Tier 1 suppliers to the automotive industry and subject matter consultants. The organization chart effectively presented the involvement and coordination of all partners comprising the product team and identified their respective responsibilities that are integrated for all aspects of the model development. The modeling tool being developed will be extremely beneficial to material developers and parts suppliers.

Reviewer 2:
This reviewer observed very good collaboration between supplier tier and university team.

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

Reviewer 1:
The proposed research is very well planned.

Reviewer 2:
The proposed future research focused on extending the current model to include data from real-world environments, integration of other damage mechanisms than those currently evaluated, and screening tests for training and validation of the model during use by a materials developer. This is a logical and reasonable approach to further development and improvement of the model, although additional critical barriers and technical challenges have not been identified by DOE. There were no risks or risk mitigation strategies identified by the presenter; however, challenges were identified by the project team that indicate an awareness of where risks may occur.

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

Reviewer 1:
The project supports DOE goals of lightweighting by enabling understanding of basic bulk material joining materials.

Reviewer 2:
This project supports the overall DOE objectives for improved integrated computational materials engineering frameworks for predictive modeling of advanced materials and prediction of corrosion-countering effects on functional resins and adhesives used in joining dissimilar materials. To some degree, the models being developed will support innovations enabled through the use of machine learning and artificial intelligence for material development and manufacturing processes.

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

Reviewer 1:
Resources for funding ($1.4 million for 3 years) to support a project team of 6 partners is sufficient for the development, limited experimentation, and validation of the hybrid physics-based model for damage by corrosion of polymeric adhesives. Milestones were achieved in a timely manner with delays occurring only because of a worldwide pandemic.

Reviewer 2:
The reviewer noted sufficient use of resources based on budget.

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)

Presenter

Miki Banu, University of Michigan

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

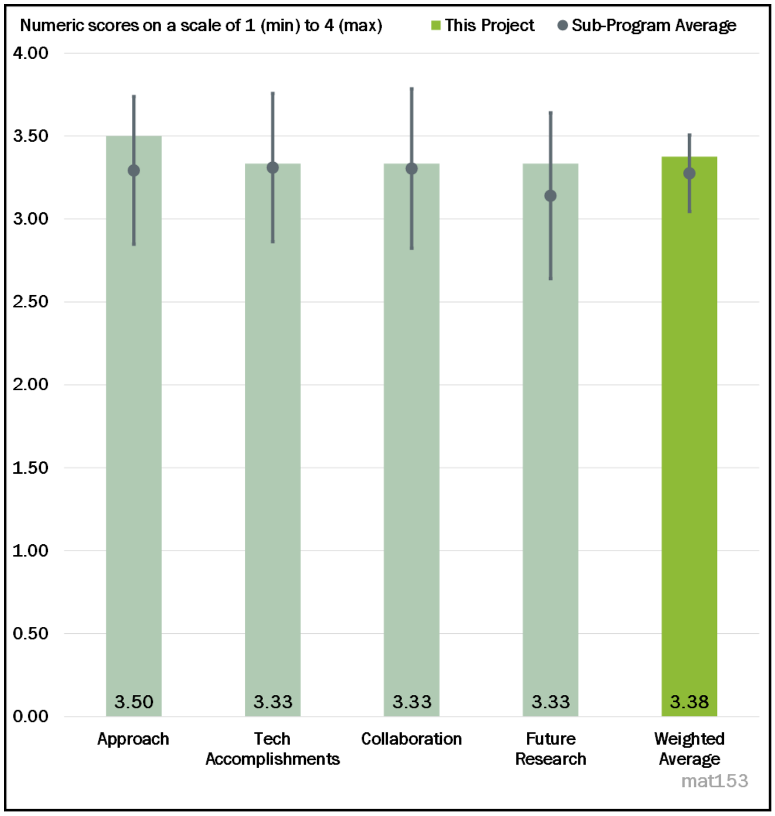

Figure 6-17 - Presentation Number: mat153 Presentation Title: Multi-Scale Computational Platform for Predictive Modeling of Corrosion in Aluminum-Steel Joints Principal Investigator: Miki Banu (University of Michigan)

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:

Great approach to a most difficult subject. Technical barriers were addressed and executed using a well-designed approach.

Reviewer 2:

The approach for this project encompasses a well-designed ICME framework with multi-scale modeling and complimentary experimental validation.

Reviewer 3:

The approach to performing the work seems to be logical. A better job could be done in tying the various aspects of the approach together for better understanding of why each element is important, and how the parts tie together to accomplish the desired goal(s).

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 excellent progress towards achieving the technical barriers in a timely manner.

Reviewer 2:
The accomplishments to date are on track. The flow of the fundamental science learned into the applied models appears to be progressing well. The deliverables themselves are also useful tools for the engineering community.

Reviewer 3:
It was difficult to understand how the current accomplishments contribute to the overall goals. There was some important information left out of the presentation of accomplishments that would have contributed to better understanding what was done and how they contribute to the eventual goal. The accomplishments currently read as a set of tasks that had been carried out. The project team does not actually describe what was achieved with regard to completion of tasks and how these contribute to the final goal(s).

Some of the acronyms used were not defined—RSW (resistance spot weld), SPR (self-pierce rivet). The authors should not assume that everyone in the audience knows these acronyms. No information was given about the composition or concentration of the salt solution used in corrosion testing. It also appears the tests were both General Motors (GM) and University of Michigan (UM) test protocols. For what does the GM protocol test? Salt exposure could simulate many things; so, what was this test(s) simulating? This was the same for the UM tests.

What was the conclusion or observation on the effect of the identified intermetallic compound on corrosion resistance of the welds? There was mention of the Al-Fe intermetallic changing from ductile to brittle upon corrosion exposure. What is the significance of this in the grand scheme of things and with regard to material degradation? For instance, does this affect stress corrosion cracking? Are there additional effects on the metal matrix with regard to the intermetallics?

What is the basis in the stress corrosion cracking (SCC) model for combining the slip dissolution model with a modified phase-field model, a decohesion model for hydrogen embrittlement and a peridynamics model?

There is lack of a single expression for any of the predictive corrosion model(s) being worked on, not even a preliminary expression. One would be good.

For corrosion nucleation, what does the project team define as nucleation? What are the parameters being used to bound the nucleation event and to separate it from propagation? What length scale is the project team working at in the nucleation phase?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This was presented as a good cohesive program, with the partners all working well together.

Reviewer 2:
The reviewer noted a very good collaboration across the project team.

Reviewer 3:
This is difficult to gauge. The majority of the work reported seems to have been carried out by UM. Perhaps the authors could shed more light on the contribution of the other team members in future presentations. Additionally, there is no mention about how communication is maintained amongst the team members. One presumes that regular team meetings and interactions occur as needed.

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

Reviewer 1:
The proposed future research to complete the program is well thought out with appropriate deliverables and timelines and a proposed strategy to overcome barriers to technology implementation.

Reviewer 2:
The plan to completion is well defined.

Reviewer 3:
More attention needs to be paid to model validation activities, which are of no use if the model can only accurately describe the data collected by the workers. The reviewer further commented that SN-curves typically do not take the effect of aqueous environment into account. How do the authors propose to use the SN curves they gather to predict failure when there is a likelihood of environment playing a role in fatigue failures with these Al-joints?

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

Reviewer 1:
The development of predictive tools to manage degradation of welds and joints is important for the effective use of lightweight materials for auto bodies.

Reviewer 2:
This program directly supports the DOE multi-material systems objectives.

Reviewer 3:
Predictive modeling of multimaterial joints supports the DOE objectives of increased efficiency through lightweighting.

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 this program appear to be sufficient.

Reviewer 2:
Resources were sufficient and effectively used to achieve project objectives.

Reviewer 3:
Based on the figures presented by the authors indicating percentage of work completed, the funds seem to be adequate. However, it is difficult with the limited information at hand for the reviewer to independently confirm whether the remaining funds will be adequate to complete the work and achieve the stated project objectives.

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 five reviewers evaluated this project.

Project Relevance and Resources

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

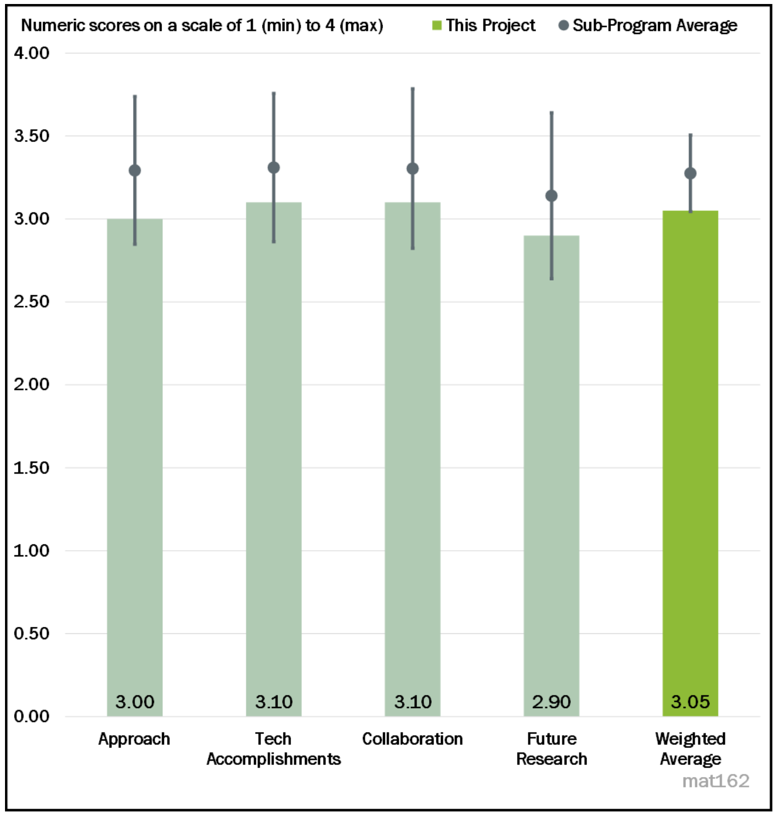

Figure 6-18 - Presentation Number: mat162 Presentation Title: Machine Learning and Supercomputing to Predict Corrosion/Oxidation of High-Performance Valve Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

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:

There is currently a wide range of research works taking place related to corrosion and oxidation of automotive engine valve at collaborating institutions and private companies. Computational and experimental work addresses the different components corrosion and surface chemistry at high temperatures. Of the major activities proposed, the first one is to develop different computational tools to predict and understand progress and behavior of corrosion or oxidation to the alloy used for automotive valve. The second is to conduct the simulation to understand the correlation between advanced alloy features and oxidations process. The third is to understand the thermodynamics and kinetics during the evolution of the oxidations process of the valve. The last is to predict oxidation behavior from the advanced alloy features with high accuracy using molecular dynamics (MD) simulations.

Reviewer 2:

It is not clear how and what kind of machine-leaning technique is being used to achieve the goal of “Predict alloy oxidation as a function of alloy chemistry and temperature and experimentally validate within 10% accuracy”. Additionally, one of the major barriers listed in the proposal is “Lack of fundamental alloy oxidation data (e.g., atomic mobilities in oxides, oxygen permeability)” However, the proposed research does not seem to have a task to directly address this barrier. Most of the tasks focus on simulation; validation of these simulation results should be equally, if not more, important.

Reviewer 3:
Focus is mostly on computational methods development to surmount technical barriers even though an experimental setup at ORNL is detailed. How will results from the computational methods be tested on real materials?

Reviewer 4:
This reviewer appreciated the fundamental background on corrosion mechanisms but had concerns that the corrosion rig test data lacked the dynamic forces due to valve actuation and cylinder pressure loading. These mechanical contributors will not be accounted for in any spallation prediction unless a subsequent correction is made, perhaps by finite element simulation or access to other test data. This work appears to only focus on the alloy chemistry and temperature effects, and is going about these efforts in a systematic method—drawing from both machine learning techniques and physics-based approaches.

Reviewer 5:
This reviewer was not clear on the approach. It sounds as though the project team is taking data, fitting a semi-empirical equation to the data, and then using the fitted coefficients to train a machine learning model. Because machine learning is essentially a fit, it appears that the project team is fitting a machine learning model to fitted parameters. Why not train the machine learning directly on the oxidation data?

Additionally, the reviewer remarked that the project team is applying its model to material in air and water vapor. What about the combustion products?

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 thought that investigators made very good progress. Excellent strengths of this project are systematic approaches regarding development of the computational tools.

Reviewer 2:
Modeling has identified key features that influence oxidation, project plan states it is on track but many of the milestones lay ahead in the fourth quarter (Q4) of 2020.

Reviewer 3:
The reviewer commented that work is progressing according to schedule.

Reviewer 4:
The project presented several interesting results. The correlation between predicted-parabolic rate constant (Kp)/experimental-Kp is plotted in log-log scale. The actual variation could still be several orders of magnitude off, especially for a wet environment. It is interesting to know what the input of ML-based prediction is in addition to chemistry composition. It is good to see the use of super-computing facility in ORNL for atomistic simulations. A methodology should be developed to validate the simulation result.

Reviewer 5:
This reviewer stated that the model seems to be predictive for nichrome (NiCr) alloy oxidation with sources of uncertainty identified. What other alloys will be attempted? Not clear how the various components of this project are integrated towards driving overall project success. Who is doing what? Who is using data/information from whom?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation it is very clear that the coordination between the three institutes is good, and the major research of this project is a highly interdisciplinary character.

Reviewer 2:
The team of ORNL and Penn State University (PSU) is a good combination. The roles of American Society for Metals (ASM) International and Tenneco powertrain are unclear in this project.

Reviewer 3:
The reason why finite element analysis is needed is not clear. What has each partner contributed to-date? How are ReaxFF simulation results being used to support finite element simulations? A brief outline of the tasks required of each participant and who has delivered what to date would be very helpful.

Reviewer 4:
The contributions from ORNL and Penn State are discussed in detail. The input from the industry partner Tenneco is unclear.

Reviewer 5:
This reviewer asked how the project team coordinates among the various institutions.

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

Reviewer 1:
The plan seems good.

Reviewer 2:
The strength of this project is very well planned and organized. Each step is very logical. One of the reviewer's concerns is related to the first principle calculations. Density functional theory (DFT) technical procedure is not clear from the presentation, specifically the RearxFF for MD simulation. It is not clear why investigators used only two different temperatures for MD simulations or only two diffusion rates. It will be better if investigators use a couple of different time scales to compare the corrosion rates at high temperatures.

Reviewer 3:
Most, if not all, of the proposed efforts focus on simulation. Some efforts should be proposed to validate those simulation results.

Reviewer 4:
How are results of the proposed future research, which is largely computational, to be used to guide experiments to test the model predictions? This is unclear to the reviewer. It seems that the focus is on computational methods development and less on new materials development. No clear path to testing model predictions was observed by the reviewer.

Reviewer 5:
A high-level data flow diagram was supplied to show how the computational pieces fit together. The supplemental machine learning material shows how machine learning can reduce experimental trials. The proposed future research appears to include expansion of the features considered, but does not clearly show how these future endeavors tie back to the project goal or will result in a final outcome/milestone. What key questions are driving these activities? What is the link between these simulation activities and a final deliverable or insight gained?

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

Reviewer 1:
Yes, focus is on improving oxidation resistance of metallic parts in high temperature engine environments.

Reviewer 2:
Fundamental research into higher temperature valve alloys supports higher power densities in internal combustion engines.

Reviewer 3:
The reviewer described this project's relevance as good.

Reviewer 4:
Yes, this project supports the overall DOE objectives. The performance of an automotive engine is depending on the corrosion or oxidation rate of the materials. New materials are needed for the fuel efficient, next generation engine, which has high corrosion resistance. In this project, proposal investigators explained the systematic approach to predict the corrosion or oxidation rate of the materials or alloys. The investigators' main goal is to develop new computational tools. Combined with the experimental and computational approach it is possible to have broad impact on the development of cost-effective, environment-friendly automotive valves for future generation.

Reviewer 5:
Corrosion prevention is important for vehicles, but how the outcome of the project can be used is not clear.

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

Reviewer 1:
ORNL and PSU have the required experience and expertise for the proposed work.

Reviewer 2:
Funding appears sufficient for the stated goals.

Reviewer 3:
Good project resources were indicated by this reviewer.

Reviewer 4:
It seems that the project has sufficient resources but suffers from a lack of clearly defined integration.

Reviewer 5:
Although, investigators made some progress regarding computational tools development, there are some unsolved questions. This reviewer's major concern is about the progress of the project. From the presentation, it is clear that investigators completed only 50% of the project. How will they finish the remaining 50% of the project and use the resources in one year?

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)

Presenter

Mei Li, Ford

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

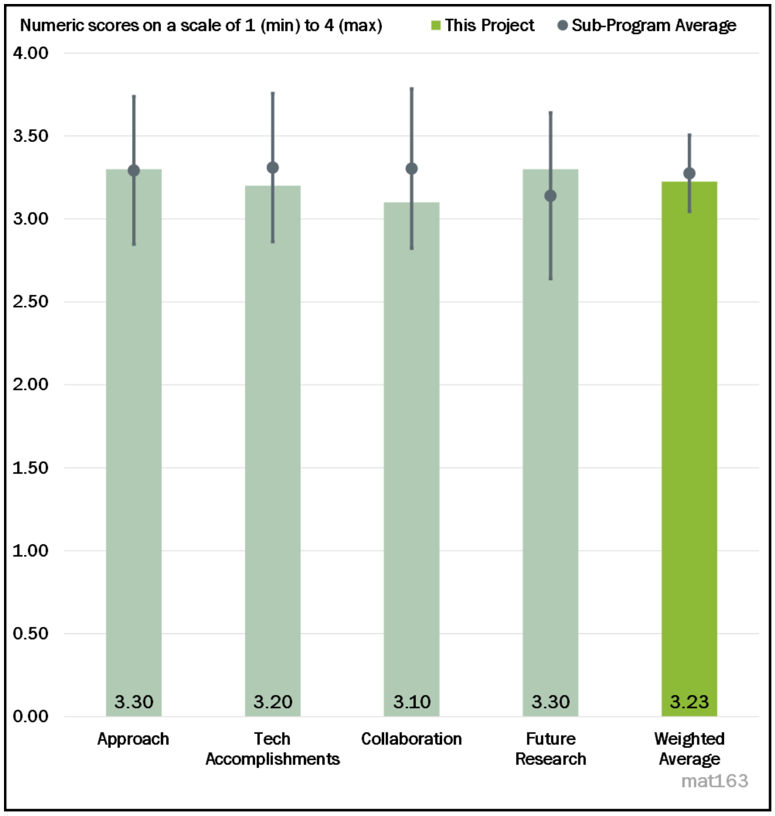

Figure 6-19 - Presentation Number: mat163 Presentation Title: Multiscale Modeling of Corrosion and Oxidation Performance and Their Impact on High-Temperature Fatigue of Automotive Exhaust Manifold Components Principal Investigator: Mei Li (Ford)

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 increased temperatures necessary for lowering carbon emissions in internal combustion engines creates an issue with any current materials commonly in use. This work was clearly targeted and well executed to move new material opportunities into the application.

The activation relaxation technique for migration mechanisms was well applied and is an important asset in this work. Much has been done on the applied thermal stresses, but this type of modeling puts the entire microstructure including the changes induced during operation into the model. Oxidation is a major concern for these components, and this work has the capability to improve that issue.

Working on exhaust manifolds is not the usual type of exciting-sounding project, but the ability to increase exhaust out temperatures gives engineers a new space to work in for combustion recipes, and this is the type of work that lays the foundation for further decreases in carbon emissions.

Reviewer 2:

Currently, there is a wide range of research related to corrosion and oxidation of automotive engine at three institutions and Ford Motor Company. Computational and experimental work addresses topics in alloy fatigue at high temperatures, corrosion, and surface chemistry. Of the major activities proposed, the first one is to develop a computational tool to predict and understand corrosion or oxidation behavior of the alloy used for automotive engine. The second is to conduct the experiment on the statics and cyclic corrosion or oxidations process on the alloys. The third is developing a corrosion or oxidation fatigue model at high temperature for the alloys. The last are experimental observations of the computational model.

Reviewer 3:
Experimental and analytical work appear to be on different scales. Linking/reconciling the two may be a challenge with the remaining project time.

Reviewer 4:
Important work of corrosion fatigue life prediction for ferrous component is undertaken in this industry led effort. Models in this area are lacking and an ICME approach can help the field advance.

Reviewer 5:
The approach seems reasonable.

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 progress is good.

Reviewer 2:
Alloy elements appear to show improvement in corrosion performance.

Reviewer 3:
Application of the modeling was well done with significant improvements over prior works in this area. The increase in exhaust temperature allowed by the materials proposed in this work can make a substantial difference in options for the combustion recipe of internal combustion engines. This work is applicable to different types of fuels, and therefore has a broad application in the market.

Reviewer 4:
The proposal aims to develop computational tools that predict corrosion and oxidation performance and their impact on high-temperature fatigue of automotive exhaust manifold components in collaboration with Ohio State University, Missouri Science and Technology, and Oak Ridge National Laboratory. From the presentation it is very clear that the investigators completed some major steps so far. They should accelerate the remaining part of the project.

Reviewer 5:
While progress is being made, a comment is made about the differences in the scale of computational and experimental approaches. For example, while the ReaXX force field and other approaches may have merit, the predictions are at a time and spatial scale that are not being accessed or even considered in the experiments.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation it is very clear that the coordination between the three institutes is good, and the major research of this project is a highly interdisciplinary character.

Reviewer 2:
This is an industry-led team with university and National Laboratory partners. The team has expertise in place for the project.

Reviewer 3:
Partners and responsibilities were listed, but it is unclear if the separate entities worked independently or if they built off of each other’s work.

Reviewer 4:
It would be helpful if the project team could provide more information about how the various part of the team interact and coordinate the work.

Reviewer 5:
The presenter did not convey a strong understanding of the computational models being employed by the project and this could increase the risk of errors and missed opportunities.

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

Reviewer 1:
The reviewer remarked that proposed future research looks good.

Reviewer 2:
Next logical steps are provided for simulation work as well as an appropriate proposal to upgrade fatigue rigs to better mimic real-world conditions.

Reviewer 3:
Excellent strengths of this project are the systematic approach about developing the computational tools. This reviewer inquired about the first principle calculations. The DFT technical procedure is not clear from the presentation, specifically the potential energy surfaces. It is not clear why investigators used only two different temperatures for MD simulations or only two diffusion rates. It would be better if investigators used a couple of different time scales to compare the corrosion rates at high temperatures.

Reviewer 4:
The proposed work in DFT calculations is a significant opportunity. The work on corrosion and oxidation is very necessary and should yield some applicable opportunities. However, there needs to be more focus on the opportunities available beyond just transmission electron microscopy (TEM) and scanning electron microscope (SEM) characterizations.

Reviewer 5:
There is no fatigue modeling planned in the future effort. Some larger scale modeling will be helpful to compare with lab experimental data that will be generated.

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

Reviewer 1:
This reviewer described project relevance as good.

Reviewer 2:
Corrosion fatigue is of concern in powertrain exhaust components and other components as well. The project supports the DOE VTO materials program objectives.

Reviewer 3:
Predictive capability for corrosion and oxidation performance in automotive exhaust manifolds as well as new corrosion resistant alloy development enables greater power density in internal combustion engines through higher temperature operation.

Reviewer 4:
Yes, the project supports overall DOE goals. The engine performance depends on the corrosion or oxidation rate of the materials. We need new materials for our fuel-efficient, next generation engine, which has high

corrosion resistance. In this project proposal, investigators explain the systematic approach to predict the corrosion or oxidation rate of the materials or alloys. The investigators' main goal is to develop new computational tools. Combined with the experimental and computational approach, it is possible to have a broad impact on developing a future generation engine.

Reviewer 5:
The work on exhaust manifolds, as with all materials on components exposed to combustion gasses, is an essential work in creating a larger combustion recipe space for engineers doing engine calibrations. The usual combustion regime is defined by the ability of materials at every point in the process. This includes things like thermal rupture on pistons, exhaust valve beat in, and deposit formation at ring lands. Without research into the ability to create cost effective materials options for components, the opportunity to increase the efficiency of internal combustion engines is very limited.

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

Reviewer 1:
Resources appear sufficient to meet project goals in the stated timeline.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
Good resources were observed by this reviewer.

Reviewer 4:
Although, investigators made some progress regarding computational tools development there are some unsolved questions. The reviewer's major concern is about the progress of the project. From the presentation, it is clear that investigators completed only 40% of the project. How will the project team finish the remaining 60% of the project and use the resources in one year?

Reviewer 5:
This is a great milestone check point but with the project only 40% complete, the big opportunity for component level demonstration lies ahead of the team. That will be the metric to prove if the resources were sufficient, if a failure mode is discovered that was not tested prior to that, or if the resources were insufficient. All PIs make decisions based on budget and level of acceptable risk. The higher the budget, the lower the acceptable risk. That is when these questions will truly be answered.

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

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

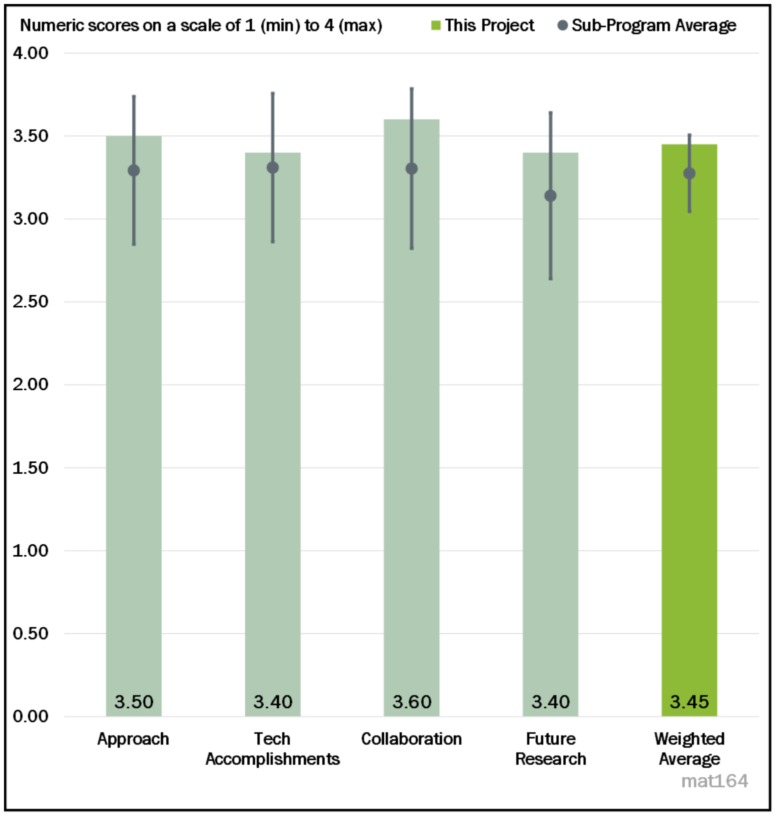

Figure 6-20 - Presentation Number: mat164 Presentation Title: Multiscale Development and Validation of the Stainless Steel Alloy Corrosion (SStAC) Tool for High-Temperature Engine Materials Principal Investigator: Michael Tonks (University of Florida)

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:

There is currently a wide range of research works going related to corrosion and oxidation of stainless steel alloy and related materials at University of Florida and other collaborating institutes. Using computational and experimental tools, this project is addressing one of the essential engine valve components. The major activities proposed including developing open source tools to model the corrosion of the different engine valves (21-2N, 21-4N, and 23-8N) at extreme conditions such as high temperature and pressure; quantifying the effect of micro-structures and alloy composition on valve steel corrosion; validating the mesoscale modeling with the help of the experimental tools; and releasing the stainless steel alloy corrosion (SStAC) tool.

Reviewer 2:

The project uses a multi-scale modeling approach to develop a tool that models corrosion behavior of stainless steel in an exhaust environment. Successful tool development could be useful.

Reviewer 3:

The approach is very focused on addressing the identified barrier of predictive modeling for corrosion of high temperature materials, specifically valves. The model development uses a multi-scale approach ranging from atomic scale to mesoscale and includes model validation using experimental results and actual full-scale engine data. The approach allows for a well-designed project that is very feasible based on modeling of materials at all levels and using experimental and operational data for validation of the modeling results. The model is based on an established platform for multi-physics objected oriented simulation developed by a

National Laboratory. The tasks identified in the project schedule Gantt chart show a logical progression of research and development of a successful tool.

Reviewer 4:
A lack of predictive modeling information for stainless steel alloys is lacking in high temperature zones that will be needed for high efficiency combustion regimes. The approach implemented by the PI is a good balance of modeling, laboratory experiments, and validation. It integrates both a nice balance of experimental and real-world data to develop the model inputs. The nano- to millimeter progression provides the baseline information to develop and assess accuracy of the corrosion model. The first publication related to this research will be released in a few months. Additionally, the reviewer noted very solid go-no/go criteria.

Reviewer 5:
This project aims to predict oxidation/corrosion behavior of stainless steel, one of the most important alloy systems for vehicles technology applications by combining different length scale simulations (i.e., density functional theory calculations at the atomistic scale, phase-field/FEM for mesoscale, and experiments). However, the handshake/data exchange between two different length scale and time scale appear to be too simple of a linear synthesis.

Most importantly, the alloy systems that the team is currently working on are too simple model alloys. The project team cannot efficiently represent engineering alloys that matter to the VTO mission space. The PI is also aware of this critical gap; however, it does not look like the team has a plan to fill this gap. In the same topic, the information that can be obtained from the atomistic length scale (e.g., DFT simulations to derive point defects and activation energies of migration) are also limited to a very simple binary/ternary system. The reviewer was skeptical about how this approach can be expanded to the higher-order multi-component systems.

For the bigger length and longer time scale, the current approach has to calibrate the model using literature data. How certain can the literature data efficiently be translated to the model used within? Are all of the features—grain size, fabrication method, heat treatment conditions—the same/similar to be used in the current model? Also, if there are no literature data to calibrate the model to make a 'pure' prediction, what is the contingency 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 proposals aim is to develop a multiscale model and validations of the SStAC tools at high temperature for engine materials in collaboration with University of Wisconsin-Madison, Idaho National Laboratory (INL), and Tenneco. Until now, the investigators' performance is outstanding.

Reviewer 2:
Simulations and experiments were performed to validate modeling data. Because the manganese oxide layer helps with performance, it is important to understand how this function will then impact the modeling and understanding of the alloy properties. From the project tests, it appears that manganese content is critical to the material performance at high temperature.

FEA was performed to assess corrosion, temperature, and mechanics on materials. This FEA was built on INL's Multiphysics Object Oriented Simulation Environment (MOOSE). This modeling integrated the impact of the alloy elements.

Reviewer 3:
The experimental data to evaluate corrosion condition seem to be the mass variation only. Does the PI consider including microstructure information? The environment created for corrosion experiment (CO_2 gas) is different

from real exhaust environment. It is interesting to know if the corrosion behavior is very different in real exhaust environment where a high concentration of oxides of nitrogen (NO_x) exists.

Reviewer 4:
The team made good progress in terms of what it promised last year for the computational tasks. However, more details on the technical accomplishments would have been appreciated. It is rather surprising that there are only three working slides in this section. What the project team accomplished is that of simple ternary model alloys with only two chemical variations—221Cr-2Ni-8.5Mn and 23Cr-8Ni-1.5Mn—based on too many assumptions. Also, it is not clear how chemical sensitivity is captured in the atomistic simulations. For example, vacancy energy formation and Fe vacancy migration energy in Slide 8 were computed at different alloy compositions?

Also, the progress on the mesoscale phase-field model appears to be a bit behind. Given the fact that phase-field modeling requires a lot of parameters within—interfacial energy and atomic mobility within both multicomponent alloys and oxides—the reviewer wondered how this information has been obtained and will be obtained to make predictions. On the other hand, progress on experimental tasks looks good. The team got samples from the cost-share partner that has a direct relevance to VTO, which is important.

Reviewer 5:
The technical accomplishments achieved for the first half of the project show good progress as measured against the tasks and performance indicators (milestones) shown in the project schedule Gantt chart. The schedule shows the first three subtasks under Task I were completed, but the technical accomplishment slides indicate that the atomistic and mesoscale models are still being developed. Some of the data could not be explained by the presenter because it came from one of the partners. The corrosion model results show that the experimental data obtained for the two alloys compare well with the literature data. The presenter did not address why variation for the error bars was so high (25% instead of a typical 15%) or why the mass variation inverted for the two alloys studied at temperatures higher than 700°C. This could indicate that the model may not be able to predict accurately at the higher temperatures. Nothing was presented on the phase field (PF) model development. Reliability of the material properties was a concern by one of the reviewers at last year's merit review of this project. There are two more sets of experiments planned; hopefully, the data will improve the model so it can be used effectively to overcome the barriers.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team consisted of a National Laboratory as well as industry and academic partners. There appears to be excellent coordination between all project partners.

Reviewer 2:
It is very clear from the presentation that coordination between the three institutes is good, and the major research of this project is a highly interdisciplinary character.

Reviewer 3:
Each team in the project has its strength and complement with each other.

Reviewer 4:
The team has good collaboration and coordination.

Reviewer 5:
The partners include a university, a National Laboratory (for consulting on the model development), and an automotive parts manufacturer. There was no indication by the presenter regarding the degree of collaboration and coordination. The cost share indicates that the industry partner will cost share in-kind by using their testing facilities. The collaboration is mostly between the university and the parts manufacturer. Federal-Mogul is

mentioned at the end of the presentation, but the presenter did not describe this company as part 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

Reviewer 1:
The project plan is excellent. The SStAC tool is a distinct outcome of this project. This tool will permit the development of lower cost, better performing alloys for valve applications in difficult operating environments.

Reviewer 2:
The experimental component of proposed research is relevant and it is great to see that the team plans to disseminate the computational tool used within the project as open-source code. It would be great if the team can put more effort into expanding the demonstrated approach to high-order multicomponent systems.

Reviewer 3:
Although investigators made some progress regarding computational tools development, there are some unsolved questions. One question is related to the first principle calculations for different properties of the alloys. Investigators did not specify what properties will be explored.

Reviewer 4:
Items listed in "Remaining challenges and barriers" are indeed critical for the successful development of the tool. The future research should be related to efforts in addressing these barriers. What methodology will the project team use to validate the developed SStAC tool?

Reviewer 5:
The proposed future research is for continuation of the project through the end of the performance period. The project team does not fully address the remaining challenges described in the preceding slide. The remaining challenges and barriers will need to be addressed to overcome the overall barriers of predictive modeling of corrosion sensitization to aid in high-temperature valve design.

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

Reviewer 1:
The project supports the overall DOE objective for improved integrated computational materials engineering frameworks for high-temperature automotive engine components.

Reviewer 2:
Yes, this project supports the overall DOE objectives by providing the knowledge needed to develop materials for lower cost, higher efficiency engines.

Reviewer 3:
This project aims to predict the oxidation/corrosion behavior of stainless steel, one of the most important alloy systems for vehicles technologies.

Reviewer 4:
Modeling methodology and toll is important to reduce the amount of costing experiment needed for process/material development.

Reviewer 5:
Yes, it is. Understanding corrosion and protecting the engine from corrosion is the key component for developing new generation lightweight engines. Different kinds of computational and experimental tools for

the predictions and the impact of the corrosion in the engine is needed. In this project proposal, investigators explain the systematic approach to developing new tools to understand the complex feature of corrosion for stainless steel alloys. Combined with the experimental and computational approach, it is possible to have a broad impact on the development of fuel-efficient lightweight engines.

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

Reviewer 1:
Yes, investigators have enough resources and are using it in a timely fashion.

Reviewer 2:
The project team has expertise and experience to finish the proposed task.

Reviewer 3:
The level of funding is sufficient for a 3-year program of predictive model development by two universities that will include experimentation for atomic-scale critical alloy properties, mesoscale corrosion evaluation, and engineering scale experiments by the parts manufacturer.

Reviewer 4:
This project appears to be on schedule and funding appears to be sufficient to complete all stated objectives.

Reviewer 5:
The team has the right amount of resources to execute the proposed research plan.

Presentation Number: mat165
Presentation Title: Directly Extruded High Conductivity Copper for Electric Machines
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 indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

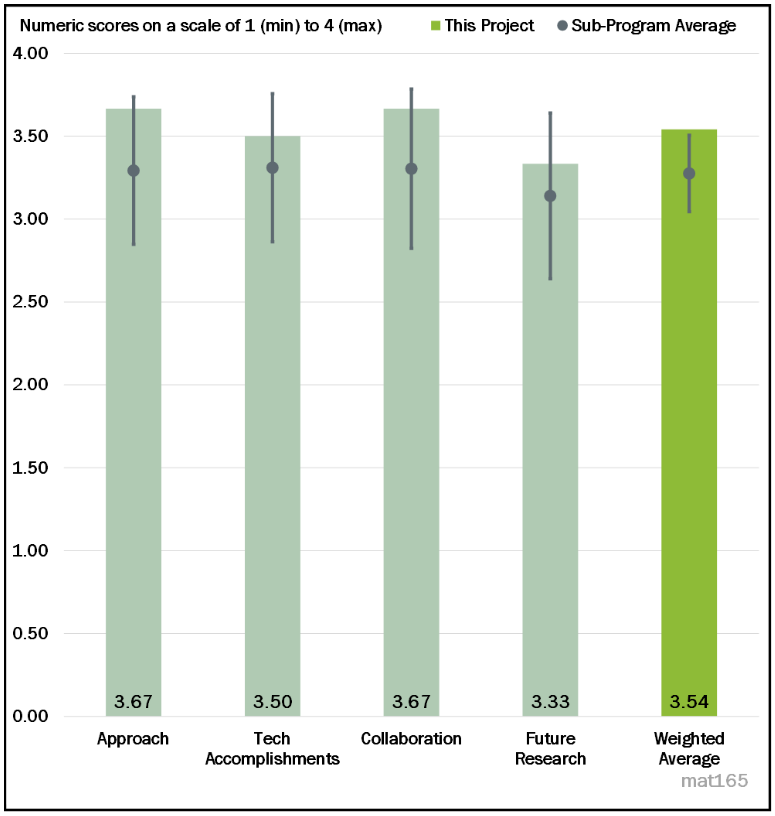

Figure 6-21 - Presentation Number: mat165 Presentation Title: Directly Extruded High Conductivity Copper for Electric Machines Principal Investigator: Glenn Grant (Pacific Northwest National Laboratory)

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 project has clear goals. The team successfully utilized its experience and infrastructure from prior development to carry out the project and the result is promising.

Reviewer 2:

The approach to improve the electrical conductivity of copper (Cu) through carbon-based reinforcement and shape processing is technically sound.

Reviewer 3:

A 50/50 cooperative research and development agreement (CRADA) has been established to share costs with partner, General Motors. The project goal is to increase power density, which will require increasing flux density capacity. To accomplish this, higher conductivity materials at increased temperatures (higher than pure Cu) will be needed. Cu is already very conductive; the only Cu additive that increases conductivity is carbon. However, the form and amount of carbon that should be added to Cu to achieve the increased conductivity at high temperature (greater than 350 K) is not known. High conductivity at increased operating temperatures is critical to allow these materials to operate during electric motor operation.

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 approach is reasonable and the project team (laboratory, industry, and university) has made appreciable progress within the scope of this effort. Scaling up to components and possible redesign of components to take advantage of improved electrical conductivity will require a separate and possibly larger effort.

Reviewer 2:
The reviewer wondered if the project team had microstructure data to evaluate the distribution of carbon nanotube (CNT) in Cu, and if it affects the final conductivity at high temperature. Long-term durability is indeed an interesting question to ask as indicated by another reviewer. It would be good to see effort related to it.

Reviewer 3:
To assess options, several forms of carbon were added to Cu using several bulk manufacturing processes to create this high conductivity Cu-C composite material. However, few bulk methods have shown promise; yet extrusion has been successfully used to achieve a high level of homogeneity. One type of extrusion processing called ShAPE was successfully used to mix and extrude wire and bar with the homogeneous mix of Cu-C composite material and can create fully dense wires from all graphene precursors. Graphene content ranges up to 6 parts per million (ppm), the graphene precursor material showed promise and very low levels of graphene increase conductivity over Cu. Continuous forms of carbon, carbon layers, bulk materials have been made defect free. The mechanical properties of Cu-graphene composite are similar to pure Cu.

Through FEA, more improvements in efficiency is possible by increasing graphene content. By increasing the graphene content, this could improve the composite material closer to the theoretical percolation limit of 150% International Annealed Cu Standard (IACS), which equates to 150% of the conductivity of pure Cu.

A material with high conductivity (and higher current carrying capacity) can reduce Cu loss (I^2R losses). This Cu-C matrix composite material has properties that can contribute to significant motor efficiency improvements.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration between the team members is excellent.

Reviewer 2:
This reviewer stated that the collaboration complements with each other.

Reviewer 3:
A path to commercialization is being established with the partners participating in this project. Several industrial motor suppliers have already expressed interest in this material.

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

Reviewer 1:
The project is nearing completion and a new effort will be required to implement the findings of this effort.

Reviewer 2:
Is there a calculation regarding the theoretical improvement on conductivity as a function of graphene content? If yes, how does the current value compared to the theoretical limit?

Reviewer 3:
A bulk manufacturing process still needs to be established. A challenge still exists; how much graphene is the optimal amount? The temperature coefficient of resistance (TCR) should continue to decrease as the graphene content is increased. The resulting materials property improvements by graphene integrated into Cu is still not understood. A very large internal PNNL initiative is now investigating the fundamental relationship of the graphene with Cu.

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

Reviewer 1:
Yes, this project supports overall DOE objectives by providing the knowledge needed to develop materials for lower cost, higher efficiency engines.

Reviewer 2:
The project is relevant for DOE's electrification objective.

Reviewer 3:
The project proposes to develop/modify material for motors, which is in line with DOE goals.

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

Reviewer 1:
This project appears to be on schedule and the funding appears to be sufficient to complete all stated objectives.

Reviewer 2:
Resources are sufficient to close out the current effort.

Reviewer 3:
The team is expected to finish (have finished 98%) what it proposed to do.

Presentation Number: mat166
Presentation Title: Aluminum Purification and Magnesium Recovery from Magnesium-Aluminum Scrap
Principal Investigator: John Hryn (Argonne National Laboratory)

Presenter

John Hryn, Argonne National Laboratory

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

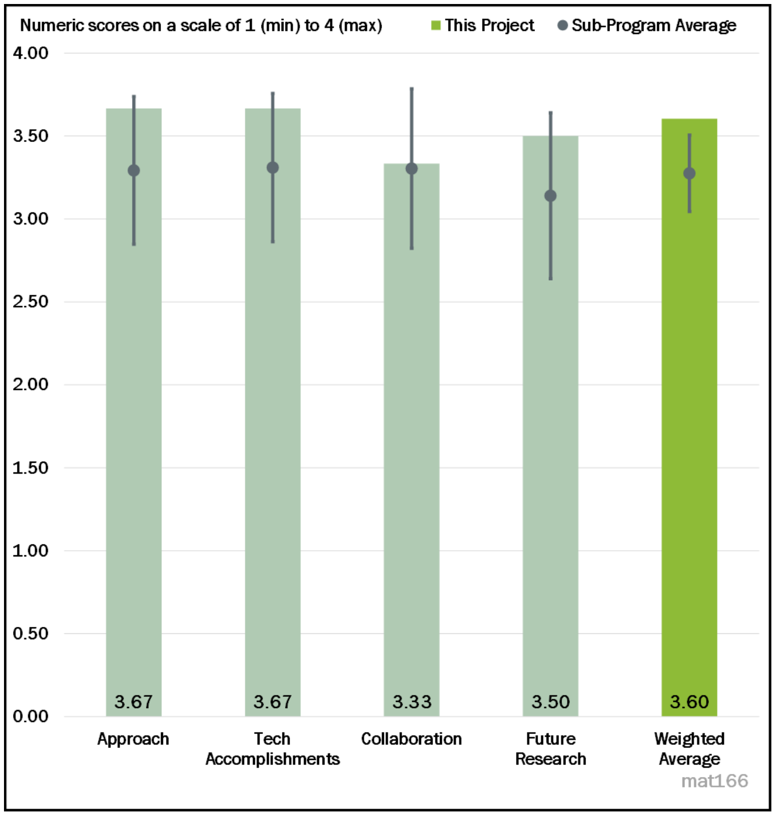

Figure 6-22 - Presentation Number: mat166 Presentation Title: Aluminum Purification and Magnesium Recovery from Magnesium-Aluminum Scrap Principal Investigator: John Hryn (Argonne National Laboratory)

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 approach seems very clear and well focused to address the technical barriers of providing a novel, reduced cost, environmentally friendly method of obtaining high purity Mg while also improving purity of recycled Al, and the approach seems well designed to accomplish that.

Reviewer 2:

This is a short, focused program on enhancing the recovery of Mg from Al scrap. The team has done a good job on delivering empirical results in a short timeframe.

Reviewer 3:

The electrolytic process to purify aluminum scrap is a good plan. All aspects including the scrap metal constitution, molten salt characterization for the electrolyte and materials for cell construction are considered. As proposed the process is continuously refining.

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:

Technical accomplishments and progress seem quite impressive for such a short-term project and well in line with addressing the critical barriers related to increasing domestic supply of low-cost, environmentally friendly

Mg. The project also reduces aluminum recycling cost as well as providing a good basis for potential future scale up efforts.

Reviewer 2:
The lab scale trial is completed after determining materials for cell construction. Also, the electrolyte selection is completed. The lab scale experiment resulted in refining small quantity of magnesium from Al scrap material. The initial trial confirms the assumption of separating Mg from Al alloy without the use of chlorine treatment.

Reviewer 3:
Significant work has been accomplished in a timeframe of approximately 6 months. This includes developing and performing experiments that include several variables and achieving excellent results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer observed appropriate team members on the project. Due to the short duration, it would be expected that the partners would need to be limited and streamlined to support.

Reviewer 2:
Good collaboration and coordination seem to be evidenced by the technical accomplishments. However, the presentation is not very detailed on who is doing what. Additionally, it is not clear if the industry partners are capable of scaling up and commercializing the process or if another industry partner will be required to accomplish this.

Reviewer 3:
This reviewer commented that a DOE lab is involved as the lead while one inventor and one testing lab are conducting the experiments in small scale. However, validation by any major producer needs to be obtained on scalability.

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

Reviewer 1:
Future research seems well planned to support scale up of technology for potential commercialization, although it is not clear if additional work will be funded because this project is claimed to be 99.9% complete.

Reviewer 2:
Regarding proposed future research, this reviewer noted increasing the cell size to check scalability. This may need another partner, major producer, or recycler, to check the feasibility.

Reviewer 3:
Technology scale up appears very reasonable going to 1 kA then 10 kA to ultimately 300 kA to exist within current smelters. One question is how long would these proposed future stages take and to what level of investment and partnership would need to be put in place to achieve?

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

Reviewer 1:
This project supports DOE's lightweighting initiatives, providing a low-cost, high-volume method to extract Mg from Al scrap. This lessens national dependence on importing Mg while potentially offering a low-cost method of extracting from scrap Al.

Reviewer 2:
The project supports increased use of both lightweight Mg and Al alloys by proposing a lower cost, more environmentally friendly process of obtaining Mg domestically while also reducing the cost of providing high purity Al alloys from recycling waste stream.

Reviewer 3:
This does not directly contribute to the DOE objective; however, this project is relevant. Magnesium production is the primary objective and recycling of scrap is the secondary objective of the project. Reducing the dependency on external sources and effective recycling are the outcomes. It is necessary to complete the work as planned now, but further support will need to be secured from other sources.

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

Reviewer 1:
Clearly, the team members were able to achieve the milestones rapidly with a relatively low investment.

Reviewer 2:
Although the budget seems thin for the amount and type of work being conducted, the project has nevertheless completed its work and appears to have met its goals within budget.

Reviewer 3:
No comments were indicated by this reviewer.

Presentation Number: mat167
Presentation Title: Corrosion Mechanisms in Magnesium-Steel Dissimilar Joints
Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

Presenter

Vineet Joshi, Pacific Northwest National Laboratory; Donovan Leonard, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

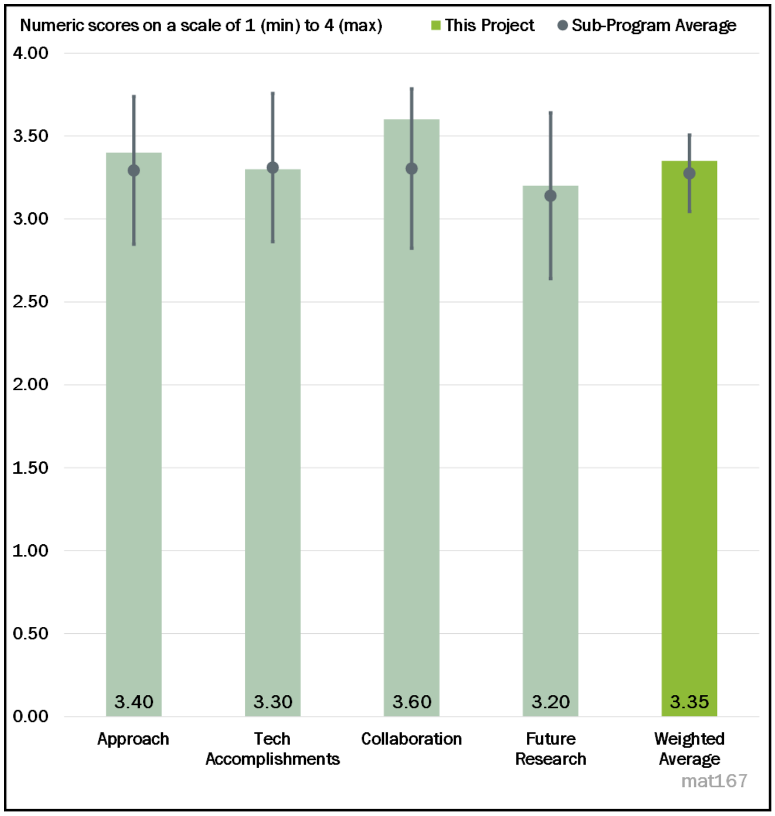

Figure 6-23 - Presentation Number: mat167 Presentation Title: Corrosion Mechanisms in Magnesium-Steel Dissimilar Joints Principal Investigator: Vineet Joshi (Pacific Northwest National Laboratory)

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 overall project approach seems well designed to support a better understanding and predictive modeling of corrosion mechanisms in multi-material (e.g., Mg-steel) dissimilar joints, both at the joint and away from the joint.

Reviewer 2:

The approach is good. Pacific Northwest National Laboratory's (PNNL) joining competence and Oak Ridge National Laboratory's (ORNL) evaluation capabilities are well integrated.

Reviewer 3:

This is a very fundamental approach to galvanic corrosion in a very commercially important system. It couples many state-of-the-art methods into a strong scientific plan. It is not well connected to industrial design practice and not fully clear if or how that gap would be bridged.

Reviewer 4:

The approaches were summarized in Slide 4, where the modeling and scanning electrochemical cell microscopy (SECCM) are supposed to guide the process optimization; however, there is no information regarding the links between these two components from the current work.

Reviewer 5:
The approach of multi-scale corrosion characterization is appropriate for the duration of the project. The deliverables are meaningful and feasible in the proposed timeframe. The biggest drawback is that this relatively short project is designed to evaluate a single set of magnesium (Mg)-steel alloys coupled together. Any alloying changes made would require revalidation of the model.

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 work is excellent and state of the art. There is excellent coupling of microstructure and corrosion. A publication would be expected but is not noted in this presentation.

Reviewer 2:
The technical accomplishments thus far seem to be on time and well in line with supporting the overall project goals with good, meaningful results.

Reviewer 3:
The technical accomplishments are good.

Reviewer 4:
The results are interesting. The fundamentals or causes behind the corrosion phenomena, however, are not presented.

Reviewer 5:
The project accomplishments are on track. Both the simulation and experimental validation experiments are progressing well and with encouraging results. The COMSOL models are limited and have not been validated yet.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaborations between PNNL and ORNL are clearly stated in the presentation.

Reviewer 2:
The collaboration between the partners appears to be fluid and meaningful, with data and materials flowing between collaborators regularly.

Reviewer 3:
The collaborators are well coordinated so that work at each is complementary to the others' in meeting project goals.

Reviewer 4:
Team collaboration seems to be quite strong.

Reviewer 5:
It appears that the collaboration between the laboratories is ongoing.

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

Reviewer 1:
The plan for future work looks very strong, and the development of design guidelines is particularly important.

Reviewer 2:
Proposed future work seems well designed to improve the understanding and predictive modeling of multi material (e.g., Mg-steel) joint galvanic corrosion mechanisms.

Reviewer 3:
Larger scale factors, such as joint configuration, may have more influences on the corrosion behavior than the local features or microstructures (the different points on the potentiodynamic curves did not indicate significant differences).

Reviewer 4:
The proposed future work covers the wrap up and transition of the current tasks but does not propose the ability to expand this project into a more universal framework that accommodates alloy changes.

Reviewer 5:
The future research is not articulated to ensure success. The scope includes understanding versus resolution or mitigation of a known joining application.

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

Reviewer 1:
Joining very electrochemically active Mg to other metals is of primary importance in next generation, multi material vehicles.

Reviewer 2:
This project supports lightweighting technologies by joining dissimilar lightweight materials.

Reviewer 3:
This project directly supports Department of Energy (DOE) objectives for multi material systems.

Reviewer 4:
The project supports the overall DOE objectives by developing a knowledge base to understand the galvanic corrosion potential of multi material (e.g., Mg-steel) joints comparing Mg-bare steel and Mg-zinc (Zn) plated steel.

Reviewer 5:
Corrosion of multi material joints is core to the application of lightweight materials to realize energy efficiency objectives.

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

Reviewer 1:
There appears to be an efficient use of resources for expensive and advanced experiments.

Reviewer 2:
The team is well prepared with the resources for the proposed work.

Reviewer 3:
The resources are sufficient for the project's stated milestones.

Reviewer 4:
Resources seem sufficient to achieve the stated milestones within the project timing.

Reviewer 5:
Resources are well balanced based on the budget.

Presentation Number: mat168
Presentation Title: Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Reinforced Composites
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 indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

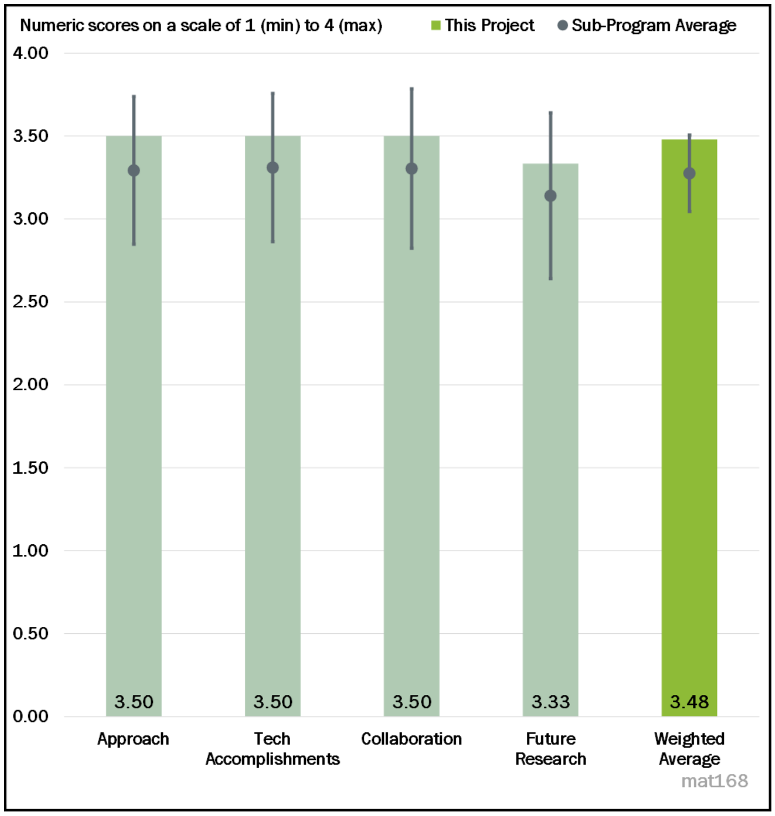

Figure 6-24 - Presentation Number: mat168 Presentation Title: Low-Cost Resin Technology for the Rapid Manufacture of High-Performance Reinforced Composites Principal Investigator: Henry Sodano (Trimer Technologies, LLC)

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:

Trimer Technologies, LLC, developed a resin transfer molding (RTM) resin with both rapid cure and significantly improved mechanical properties. The approach is novel, and the results are encouraging.

Reviewer 2:

The approach uses a proprietary resin to overcome all the barriers and meet all technical targets. Because the primary technology (e.g., the resin) is proprietary, no information is presented on its composition or the cost, so addressing the DOE technical target of cost effective systems will need to be addressed for a full-scale system if the project is funded in Phase II. The project is well designed, and the results were obtained using a systematic approach of resin characterization, curing parameters, and molding characteristics. For a low budget, short term project, the results were impressive in meeting technical targets for potential high volume processing of carbon fiber composites in multi-layers and improved inherent resin-fiber bonding. An additional technical target for a fire retardant composite was achieved, although it is not a current DOE technical target for automotive materials.

Reviewer 3:

The project team listed several positive attributes of the resin system, such as:

- Low viscosity for rapid infusion

- Rapid cure
- High strength, stiffness, and toughness
- Nonflammable
- High glass transition temperature (Tg)
- Goals of reaching high pressure (HP) RTM cycle times.

However, there was really no basis to judge what the resin system or what chemistries are at play. While it is understood that some information may be proprietary, the reviewer indicated it was very difficult to make an assessment of the merits of the system with no basic idea of the chemistry and environmental implications. This was a main weakness.

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 a 1-year project, the results for a high strength polymer with a low viscosity for better wetting of the fibers and significantly reduced process cycle times were quite impressive. Resin properties for the Tg, tensile strength, modulus, strain, and compressive strength far exceeded the properties of other commercial resins, which indicates that the carbon fiber (CF) composites made with this resin have a high probability of meeting or exceeding DOE's end product goals for strength and modulus. The high viscosity at low temperatures and stable lower viscosity at higher temperatures for several minutes are good characteristics of a resin than can be used effectively in HP-RTM processes. The cure rates presented were significantly lower than typically experienced in production, which will certainly contribute to cost effective high volume processing. The lamination of several fiber layers produced reasonable strength results for a small sample. All milestones for the performance measures were met.

Reviewer 2:
Phase I has been very successful, with encouraging results and the potential to achieve a cycle time of 1 minute or less.

Reviewer 3:
The reviewer would like to reference prior comments from criterion B. On Slide 7 where the project team lists Trimer's resin, alongside systems such as Dow Chemical, Huntsman, AOC, and Reichhold, the Trimer values are significantly higher. While this is commendable, without a scientific basis, it is not possible to make a reasonable judgment. Looking at the slides, yes, the technical accomplishments and progress are excellent; however, as a scientific reviewer, the information presented is very spare to make a reasonable evaluation.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project team consists of a resin manufacturer, a parts manufacturer, a composites manufacturing scale-up facility, and unnamed original equipment manufacturers (OEMs). Collaborative efforts appear to be well coordinated, with equal participation from all partners. Collaborations cover the full spectrum, from materials development to manufacturing.

Reviewer 2:
Trimer has been collaborating with the Institute for Advanced Composites Manufacturing Innovation (IACMI) Scale-up Research Facility (SuRF) and TPI Composites and plans to move to Phase II to advance to commercialization.

Reviewer 3:
The project team's collaboration with TPI and IACMI seems good. However, at this stage of the project it was not possible to determine the success or steps taken for this collaboration. Supposedly, that will emerge downstream 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

Reviewer 1:
The Phase I Small Business Innovation Research (SBIR) project has ended, but with the results from Phase I, there is a high probability that work will continue. The project has successfully progressed from a new resin material to small-scale testing of composites fabricated with the resin using a well-known commercial process. The proposed future research logically progresses to the involvement of Tier 1 suppliers and OEMs to assist with development of prototype scale processing parameters and characterization of the prototype parts. The presenter also addressed the coordination with OEMs to establish production tooling for specific applications, such as battery enclosures for electric vehicles (EVs).

Reviewer 2:
The proposed future work lays out a good pathway to continue the development of Trimer's HP-RTM, and the project team has already submitted a Phase II proposal.

Reviewer 3:
The proposed future work is both on the technical and commercial side. The project team is looking to expand process development and material testing with a goal of generating sufficient data toward commercialization. The team is looking toward process development, which necessitates rheology and kinetic studies, and will develop an internal mold release per the claim. Resin adoption in high volume automotive manufacturing requires scale-up of the manufacturing process. Component level testing will be required for commercialization. The team will develop relationships with OEMs based on the above. While these are reasonable, the vagueness of the information continues to occur when the team talks about future research. There is very little concrete information that could be gathered.

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

Reviewer 1:
If the technology successfully transfers to vehicle manufacturers, then the DOE goals for cost effective designs, high volume composites processing, joining of multi-materials, and lightweight structural automotive components will be met or exceeded.

Reviewer 2:
Trimer's resin has shown less than 1-minute cycle times. This is important for cost reduction for vehicle composite manufacturing.

Reviewer 3:
The project aims to reduce cycle times and provide resins with higher performance, which will benefit DOE's lightweighting goals.

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

Reviewer 1:
For a 1-year SBIR research effort, the funding and research companies involved were sufficient to meet the project milestones and goals in a timely fashion. Funding of $200,000 per year for characterizing the resin properties and small-scale testing was sufficient.

Reviewer 2:
Trimer has been working with IACMI-SuRF and TPI to leverage resources and has made progress in a timely manner.

Reviewer 3:
It was not possible to judge accurately on this, but it appears the team has the resources.

Presentation Number: mat169
Presentation Title: Short-Fiber Preform Technology for Automotive Part Production
Principal Investigator: Dirk Heider (Composites Automation, LLC)

Presenter

Dirk Heider, Composites Automation, LLC

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

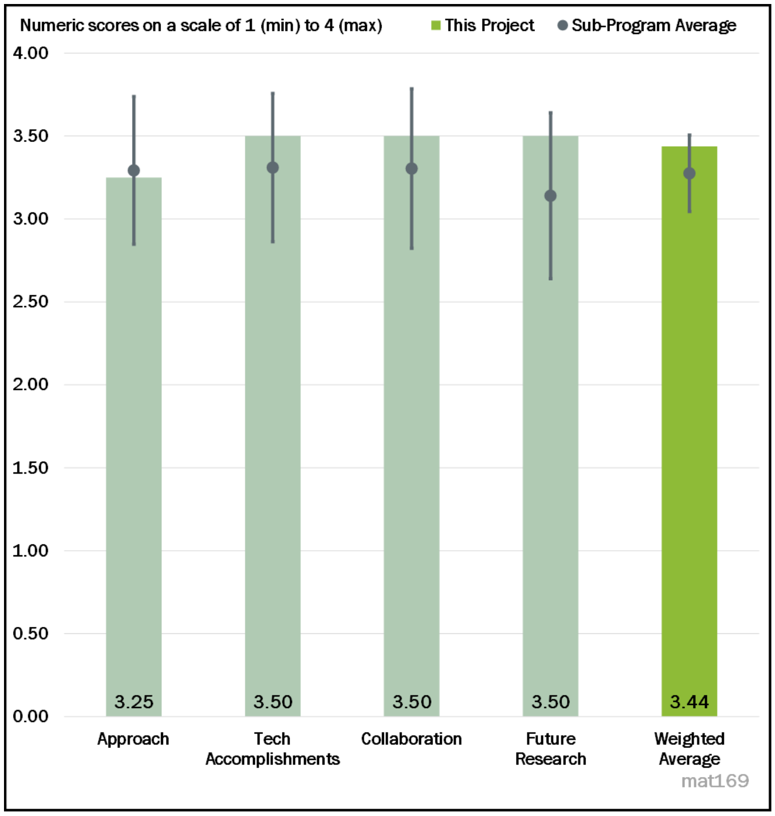

Figure 6-25 - Presentation Number: mat169 Presentation Title: Short-Fiber Preform Technology for Automotive Part Production Principal Investigator: Dirk Heider (Composites Automation, LLC)

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:

Composites Automation uses tailored universal feedstock for forming (TuFF) to eliminate preforming challenges, allow the use of recycled fiber, and enable at-rate production and lower cost. This might lead to a paradigm shift in composite processing.

Reviewer 2:

The approach for using tailorable feedstock and forming to reduce the cost of raw materials through reuse of CF materials is effective and contributes to overcoming the DOE target of low cost, high production fiber feedstocks and composite preforms. The process described in the approach is attractive from the aspect of material recovery and reuse and minimal waste. Other technical barriers and DOE targets such as weight reduction, material properties for end products, and innovative architectures are not addressed by this very short (9 month) Small Business Technology Transfer (STTR) project. The survey of commercially available, low cost CF was not comprehensive, but was sufficient to compare TuFF technology with commercial materials, and the presenter indicated that discussions were started with major suppliers of CF and CF products.

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 short period of performance, the progress presented for the tasks described in the project schedule Gantt chart on Slide 2 indicates very good technical accomplishments and project performance as measured against the performance indicators (milestones). A significant amount of aligned CF material was produced with consistent areal weight, which is a good feature for preform material. The evaluation of aerosol spray and veil materials for binders gave good technical results for the veil material, which is also a good approach for fabrication of preforms on a commercial scale. The evaluation of an electro-spun veil material showed a novel approach for improving and optimizing the manufacture of the final fiber product. Preliminary results for fiber strength and modulus show improved properties over a well-known commercial fiber, and projected even further improvement with an increase in the full volume fraction. The cost comparison was adequate to evaluate as-manufactured material costs. The costs did not directly relate to automotive component cost reductions of less than $5 per pound saved, but the presenter alludes to the fact that recycled fibers have the long-term potential to meet the DOE goal of less than $5 per pound for the base CF material.

Reviewer 2:
The team fabricated uni-directional, thin-ply CF sheet material and cross-ply CF preform material. Flat coupons were used for mechanical testing, and the preliminary results are encouraging.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This is a short term Phase I STTR project and should not be expected to have extensive collaboration with multiple partners. The collaboration was between a material developer and a university. Coordination between the two performers is good and well coordinated.

Reviewer 2:
The team collaborated with the University of Delaware and reached out to ORNL's Carbon Fiber Technology Facility (CFTF), Zoltek, and the SGL Group.

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

Reviewer 1:
The proposed future research focuses on stabilizing the process, selecting an automotive part, testing the automotive part, and manufacturing cycle time and cost. This is a logical follow-on to the progress and accomplishments in Phase I and appears to be well planned. The company plans on working with manufacturers of resins and automotive parts to transfer the technology to OEMs. Risks are not addressed, but this is mostly process development which has fewer and lower risks than material development.

Reviewer 2:
The team lays out a very good pathway to move to Phase II to advance to commercialization.

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

Reviewer 1:
The technology and process development presented supports the overall DOE objective for low cost, high production fiber feedstocks to meet the needs of the automotive industry. Other DOE requirements and targets for end-product material performance and production volume were not addressed at this stage of research but should be addressed if the proposed future research is funded and executed according to the project plan.

Reviewer 2:
The TuFF process has demonstrated capabilities for net shape preforming and reuse of fiber waste.

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

Reviewer 1:
For the very short performance period (9 months), the funding level is sufficient for the two agencies conducting the research. Additionally, the presenter indicated that the TuFF material was initially developed under a Defense Advanced Research Projects Agency (DARPA) program, so much of the early research on the technology was already funded and testing, requiring minimal resources.

Reviewer 2:
The team used the resources of Composites Automation and University of Delaware and reached out to ORNL CFTF, Zoltek, and SGL.

Presentation Number: mat170
Presentation Title: Embedded Networked Elements for Resin Visualization and Evaluation (NERVE) System for Intelligent Manufacturing of Multifunctional Composites for Vehicles
Principal Investigator: Amrita Kumar (Acellent Technologies, Inc.)

Presenter

Amrita Kumar, Acellent Technologies, Inc.

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

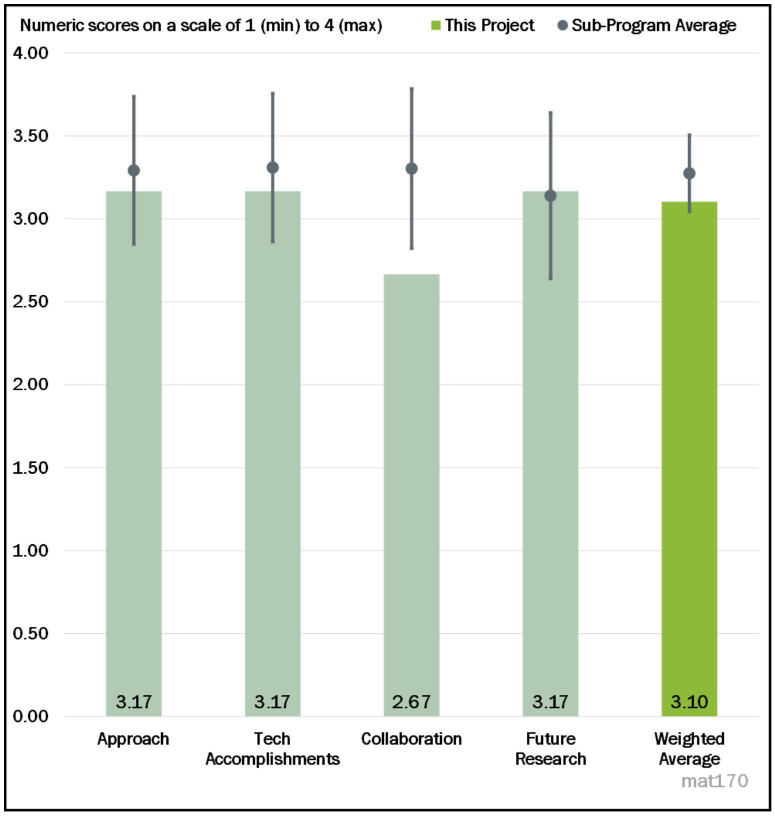

Figure 6-26 - Presentation Number: mat170 Presentation Title: Embedded Networked Elements for Resin Visualization and Evaluation (NERVE) System for Intelligent Manufacturing of Multifunctional Composites for Vehicles Principal Investigator: Amrita Kum

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 demonstrated a Networked Elements for Resin Visualization and Evaluation (NERVE) system consisting of embedded actuating and sensing elements to monitor and enhance all phases of the composite manufacturing process used in the automotive manufacturing industry. The NERVE system may find applications in composite structure health monitoring.

Reviewer 2:
While the approach of embedding piezoelectric sensors in composite laminates is not entirely new, there is prior work on this (see the Smart Materials & Structures Journal, SMARTweave at the Army Research Laboratory, and other related works), the work is very thorough and practical for implementation in real manufacturing. The approach is to conduct proof of feasibility during manufacture and measuring the sensor response over a period of time.

Reviewer 3:
The approach focuses on the technical feasibility but not on the robustness, costs, or other aspects of the 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 team has demonstrated good sensitivity and selectivity of the NERVE system. Phase I has been very successful.

Reviewer 2:
In the initial work, the team has demonstrated embedding a smart piezoelectric sensor in a composite laminate. The team developed a curing algorithm to accurately predict the onset and progression of the cure. The tool also went on to be used for damage detection. The team claims a reduced manufacturing time of about 30% from the data obtained from the sensor. Items that were not entirely clear to this reviewer include the following: material systems; laminate thickness; locations of the sensor (and if this is a factor in the sensitivity); and amount of complexity in accessing the sensor during manufacturing. These are factors that would influence manufacturing ability. Supposedly, these will be considered as the project progresses.

Reviewer 3:
There are solid technical accomplishments but no mention of the return on investment (ROI) that was claimed to have been accomplished.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between Acellent and the University of Delaware was excellent, and the team plans to apply for Phase II to continue the development of the NERVE system to advance it to commercialization.

Reviewer 2:
At this stage of the project, it was not entirely clear what the University of Delaware is doing, or if all the work is being performed there and the company is primarily providing the sensor and conducting data analysis. However, this may get more streamlined as the project progresses. Bavarian Motors Works (BMW) and Armor Works have been identified as collaborators. It was not clear what their role was or is going to be as the project progresses.

Reviewer 3:
While the University of Delaware was mentioned and credited, the division of tasks, the roles and responsibilities, and the types and frequency of the interactions were not mentioned.

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

Reviewer 1:
The project has well defined decision points with go/no go. The Phase I has demonstrated feasibility and results are encouraging for moving to Phase II.

Reviewer 2:
The project team’s progression to the next steps are logical. The team will evaluate the sensors both in the laminate and the tool. No details are known about the sensor integration in the tool— location, type of tooling (steel, Al, non-metallic?), number of sensors, hardware access, etc. These will all play a role in the practical utilization of these sensors. Also, the reviewer wanted to know if the sensors are only limited to autoclaves or how do the sensors offer many process options. If that is not a restriction, that must be somehow articulated to demonstrate wider utilization.

Reviewer 3:
The proposed future work is for the (currently unfunded?) subsequent phase. The efforts to ramp up to pilot scale and prove the technology in a manufacturing environment is appropriate. The reviewer hoped that the future phases will have technical cost modeling to more effectively gauge the value of the developments.

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

Reviewer 1:
The NERVE system has the demonstrated capabilities of optimizing the composite manufacturing process; improving manufacturing quality; increasing throughput by optimizing production rate; eliminating the need to scrap components due to poor quality; and reducing overall costs by eliminating time consuming, post fabrication inspections leading to high volume production use in automotive industries.

Reviewer 2:
Improvements in the manufacturing of composites will likely reduce the costs barrier for automotive OEMs to reduce weight.

Reviewer 3:
The key finding is the reduction of manufacturing time, which the team claims is about 30%. If so, there are cost and energy saving implications which are of importance to DOE. While the team demonstrates the sensor in an infusion type of process, DOE relevance may also need information for processes like fast compression molding and pre-preg stamping for high rate processes. Will the sensors survive those types of automotive relevant processes, or are the sensors limited to liquid molding only?

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

Reviewer 1:
The team used the facilities at both Acellent and the University of Delaware to advance the project in a timely manner.

Reviewer 2:
Resources are sufficient.

Reviewer 3:
It was not clear what resources are at the company, and how much is being leveraged from the University of Delaware. Overall, the team seems to have the resources to execute the work.

Presentation Number: mat171
Presentation Title: Discontinuous Low-Cost Carbon Fiber/Bamboo Fiber Hybrid Intermediates for Lightweighting Vehicle Applications
Principal Investigator: David Knight (Resource Fiber, LLC)

Presenter

Lee Slaven, Resource Fiber, LLC

Reviewer Sample Size

A total of two reviewers evaluated this project.

Project Relevance and Resources

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

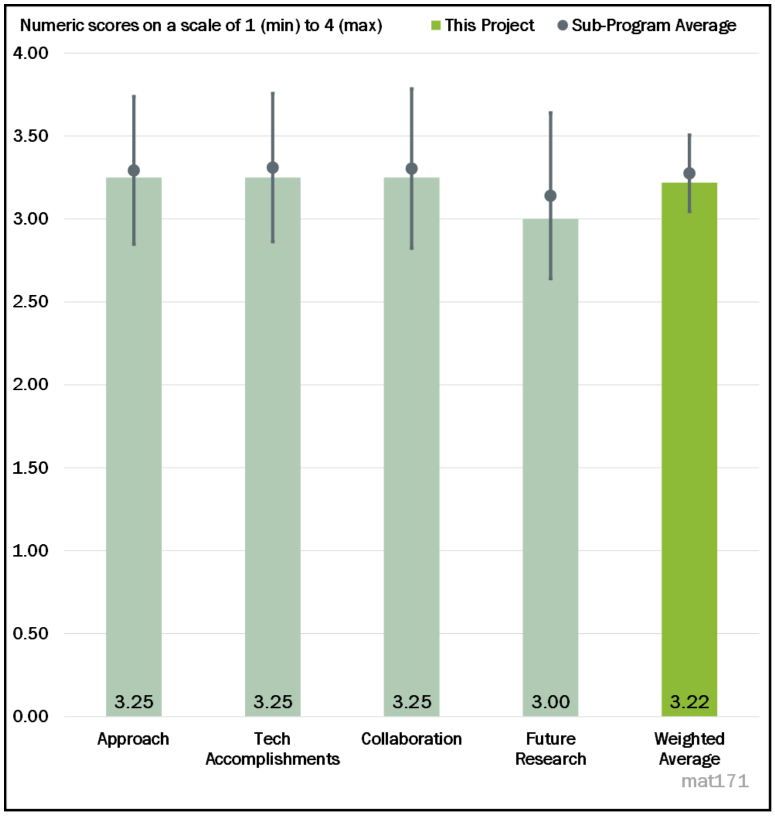

Figure 6-27 - Presentation Number: mat171 Presentation Title: Discontinuous Low-Cost Carbon Fiber/Bamboo Fiber Hybrid Intermediates for Lightweighting Vehicle Applications Principal Investigator: David Knight (Resource Fiber, LLC)

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 used hybrid bamboo fibers and CFs to reinforce polypropylene (PP). This is very creative. The approach is novel and the results are solid and of great interest. The composite cost is reduced by using less CF.

Reviewer 2:

There is a good design of experiments approach to this proof of concept 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 project is on track and in good shape. The team works on the remaining milestone (which is delayed due to COVID-19,) with the hope to wrap up the project by the end of June 2020.

Reviewer 2:

Testing was complete and detailed. The reviewer had hoped to see the error bars, number of samples, and other details that would speak to the robustness of these material test results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration was excellent between Resource Fiber, the University of Tennessee at Knoxville (UTK), and IACMI.

Reviewer 2:
Good results usually result from good cooperation. This presentation does not mention division of tasks, roles and responsibilities, and the frequency of meetings.

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

Reviewer 1:
The team plans to extend the research to Phase II to advance to commercialization.

Reviewer 2:
The project has ended. The future challenges for a potential Phase II project have been identified. However, there needs to be technical cost modeling to ascertain the value of any developments.

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

Reviewer 1:
CFs are expensive for vehicle applications. The team used bamboo fibers to reduce CFs, which is quite novel.

Reviewer 2:
Reducing the costs of high performance composites will lead to lighter weight vehicles.

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

Reviewer 1:
The team used all possible resources and made progress to the overall objective. Due to COVID-19, the last milestone was delayed.

Reviewer 2:
Resources are sufficient.

**Presentation Number: mat172
Presentation Title: High-Performance Fiber-Reinforced Vitrimer Composites through Compression Molding
Principal Investigator: Yinghua Jin (NCO Technologies, LLC)**

Presenter

Yinghua Jin, NCO Technologies, LLC

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

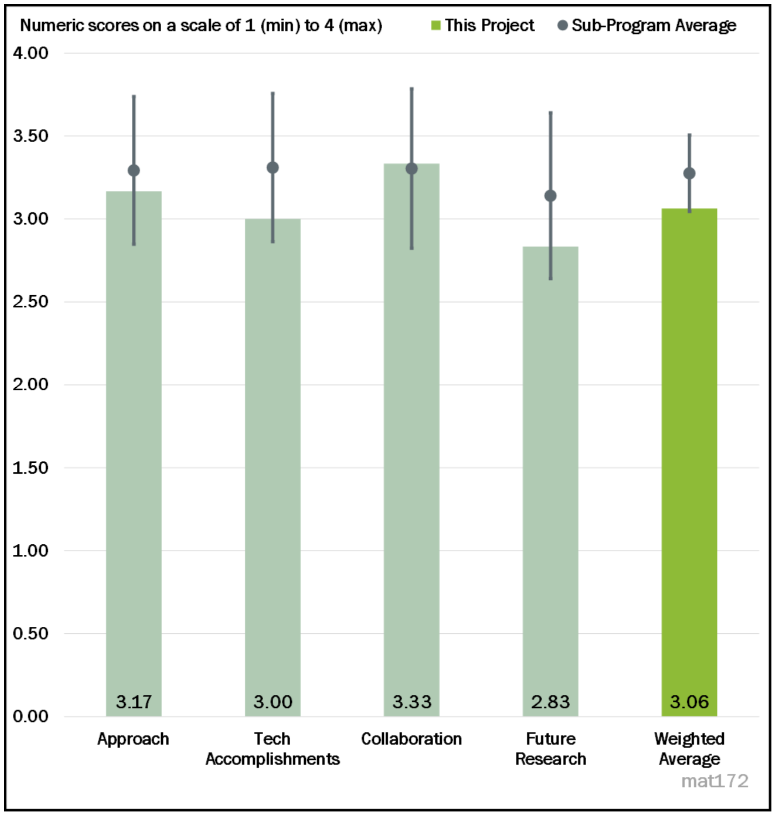

Figure 6-28 - Presentation Number: mat172 Presentation Title: High-Performance Fiber-Reinforced Vitrimer Composites through Compression Molding Principal Investigator: Yinghua Jin

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 use of vitrimers as polymer binders in carbon fiber reinforced composites (CFRCs) is novel and may find more applications in other polymer composites. The results from recycling CFRCs are very useful. The reviewer appreciated the closed loop approach.

Reviewer 2:

The project team proposed a reversible resin chemistry via vitrimers in the approach. The team aims to achieve fast bond exchange reactions at an elevated temperature to enable vitrimer particle fusion and interface healing through bond exchange reactions during compression molding, as well as depolymerizing the polymer matrix by upsetting the stoichiometry of the end groups at the end of product life. Overall, the approach has merit, but there was very little by way of the system chemistries to make an evaluation of scientific merit.

Reviewer 3:

The team has a good approach to this initial study on vitrimer composites with CF. The approach could have been improved with more span to the studies on gauge (perhaps 1-5 mm thickness and different types of CF composites).

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 demonstrated fast-moldable vitrimers with good mechanical and thermal properties. The fast compression molding technique to form CFRCs was done in a short processing time of 2-3 minutes. This is a big deal in CFRC manufacturing.

Reviewer 2:
The team has proven the initial concept of this technology. The compression molding was accomplished. The progress would have been more substantial if the number of recycling and reprocessing attempts had been investigated and reported. The reviewer was curious as to what happens as over 95% of the vitrimer and CF composites is reused 10, 20, or 100 times.

Reviewer 3:
Some of the comments made under Quarter 2 (Q2) apply here as well. For example, on Slide 6, the team calls out vitrimer 1 and vitrimer 2 without providing any context of what these are or what the differences in these systems are. The reviewer wanted to know what are the relative viscosities of the system, processing issues, and parameters of any of these? Slide 7 has similar issues and it was not clear how the team is processing the vitrimers with the carbon fabric (sheet, film, bulk?) and how the team is ensuring good dispersion. While some of this information may be proprietary, as a reviewer, there was no basis to make an objective statement.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between NCO Technologies, LLC, and the University of Colorado at Boulder to advance the project was excellent.

Reviewer 2:
There is a clear division of tasks. The reviewer would like to know how often joint meetings were conducted and if any team members were collocated.

Reviewer 3:
The work is in its early stages. The collaboration with the University of Colorado at Boulder should expand in the coming periods. Also, the roles of who did what was not clear. The results thus far are very laboratory scale and seem to be generated at the university.

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

Reviewer 1:
The team has demonstrated many encouraging results, and the vitrimers should find more applications in vehicle structures. The project lays out pathways to future studies. Although the principal investigator (PI) mentioned that the team was not going to apply for Phase II, the team may seek industry and other funding sources for future work.

Reviewer 2:
Future work would be enhanced with a technical cost model to ascertain the value of this technology.

Reviewer 3:
The team plans to continue working on the development of the vitrimers and reduce processing times and will also evaluate reprocessing, weldability, and repair. These are good goals, but it would be good to first see

robust laminates and laminate data before going on to these steps. The chemistry optimization seems to be needed first, or at least was not presented here for a meaningful review.

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

Reviewer 1:
Vitrimers are novel, malleable thermosets with many distinct advantages that would offer significant environmental and economic benefits. The team is encouraged to do more fundamental research and advance to commercialization.

Reviewer 2:
DOE is looking at various technologies for recycling of its systems, and this work has the potential for this in the long term. The work is still very early stage.

Reviewer 3:
This could reduce the mass of parts in cars and trucks to improve 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 team uses the resources from both NCO Technologies and the University of Colorado at Boulder, making progress toward the objectives.

Reviewer 2:
There are sufficient resources for this initial study.

Reviewer 3:
It was not clear who has what, but the team seems to have the resources for conducting the work. Work definitions need to be lot clearer.

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

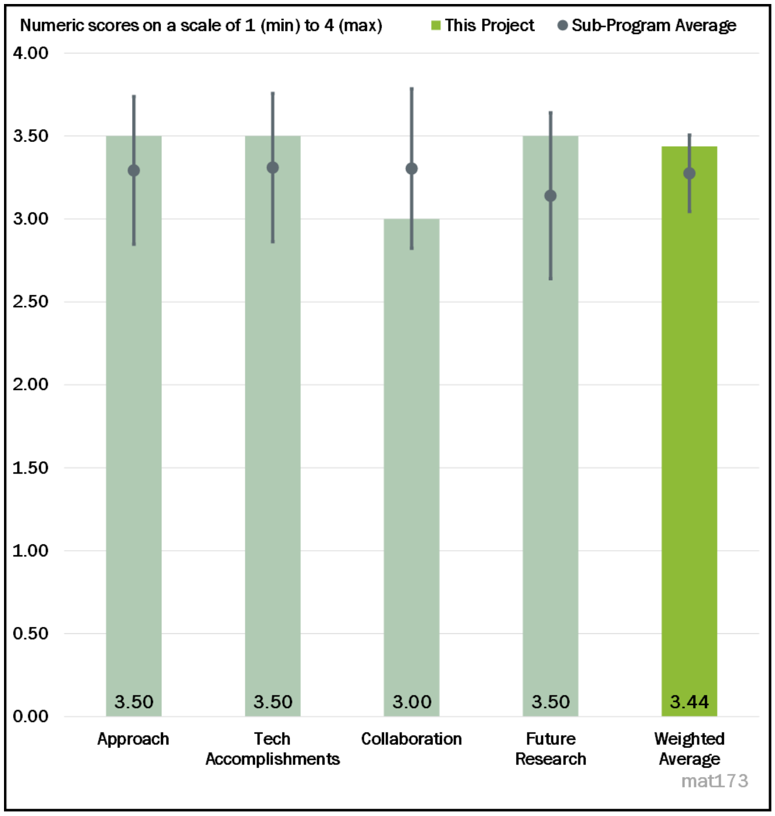

Figure 6-29 - Presentation Number: mat173 Presentation Title: Self-Sensing Fiber-Reinforced Composites Principal Investigator: Christopher Bowland (Oak Ridge National Laboratory)

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 appreciated the approach taken by the research team using titanium dioxide (TiO_2) nanoparticles to demonstrate “roll-to-roll” processing and results through thickness sensor performance as a function of applied strain. With the additional benefit of excellent surface dispersion and improved interlaminar shear properties demonstrated, there is a compelling argument to pursue this course. Well done.

It would have been helpful to better understand the approach planned (by schematic, identification of potential hardware, or simple description) by the team to pursue wireless applications. The use of drones to perform autonomous inspections is very attractive for other critical infrastructure (for example, wind turbines).

Reviewer 2:

By using a roll-to-roll fiber processing method to add various nanoparticles to the fiber surface, the project is able to produce a multifunctional composite with structural health monitoring capabilities. Structural health monitoring would help inform models for in-service performance prediction and would allow for an optimized design while minimizing cost.

Reviewer 3:

The approach is very innovative in creating a fiber sensing capability by deposition of nanoparticles on the fiber surface. This is a new project, and this was the first review of this project. The team investigated a roll-to-roll dip coating deposition process to integrate nanoparticles into the sizing for improved mechanical strength and sensing functionality.

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:
As the reviewer suggested in prior comments, the progress shown by this team in a year's effort (for the dollars expended) is quite good. The improvement in transverse shear properties is quite significant, and the progress to demonstrate the potential capability to work as an active strain sensor is similarly important and demonstrates outstanding progress.

Reviewer 2:
The multifunctional composite produced is shown to have a 14.7% increase in interlaminar shear strength (ILSS) and a maximum gauge factor increase of 187%.

Reviewer 3:
The initial results seem promising. The team demonstrated a 14% improvement in ILSS with just 1% nanoparticle loading. Also, the gauge factor was seen to increase by 187% with 2.5% weight nanoparticles.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
While the reviewer had no explicit criticism of the research team, the project progress reported would seem to be the result of the ORNL research effort and the collaboration of interns (commendable as well) working on the ORNL campus. It is not clear how Dronesat, LLC, will participate in the research effort. There appears to be a straight line connection between the success of the fiber sensor as a wireless communication element in a structural health monitoring application that is performed by drones, but the reporting does not provide a complete picture of how or when Dronesat participates. Clearly, the results and progress speak well of the operation of the research team.

Reviewer 2:
The collaboration with Dronesat has offered the research product (multifunctional composite) a great platform for demonstration of its capability and benefit.

Reviewer 3:
The collaboration with Dronesat is not entirely clear. Perhaps that aspect will shape up later in the project. The work is primarily conducted at ORNL at this stage.

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

Reviewer 1:
The team's proposed future work is logical and in line with the work. The team plans to coat fibers with ferroelectric nanoparticles, measure electrical and mechanical properties, evaluate wireless sensing, reinforce thermoplastic matrices with passive sensing fibers, and evaluate hybrid composites and passive sensing composites. These are reasonable future tasks.

Reviewer 2:
The research team did an excellent job of describing the upcoming work in pivoting from the TiO_2 nanoparticles to barium titanate ($BaTiO_3$) to create a passive sensor capability. The step associated with this proposed work is well described and appears feasible and attainable. The reviewer would simply liked to have seen a bit more detail regarding plans to create a wireless communication capability.

Reviewer 3:
Passive sensing with wireless communication will enable monitoring of in-service degradation of materials and will increase composite safety or provide an estimation of maintenance requirements. Since many materials are subject to cyclic loading in service, it would be good to have some data on the impact of the new fiber coating on the fatigue of the composites.

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

Reviewer 1:
DOE has clearly expressed the importance of expanding the use of high specific strength and stiffness materials (i.e., CFRPs). The advancement of effective condition monitoring technologies that improve structural reliability and provide insight into condition will allow for higher levels of user confidence and will expand utilization. That supports this goal and will ensure a continued trend of lightweighting of transportation systems.

Reviewer 2:
Multifunctional materials will enable a wide application of composites, especially in some special applications where material electrical conductivities and/or in-service integration is critical. That will contribute to DOE VTO lightweight objectives.

Reviewer 3:
The work aligns with DOE goals of creating multi-scale, multifunctional composites that have an overall lower carbon footprint. The future of this work is leading to that goal.

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

Reviewer 1:
The funding level is quite modest, but the work performed and progress reported suggest that the resources are sufficient. The reviewer was curious about whether additional funding to support specific real applications should be considered at the conclusion of this foundational work.

Reviewer 2:
The project is achieving its objective.

Reviewer 3:
The team has adequate and high-quality resources through the Manufacturing Demonstration Facility (MDF) at ORNL and through partners.

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 three reviewers evaluated this project.

Project Relevance and Resources

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

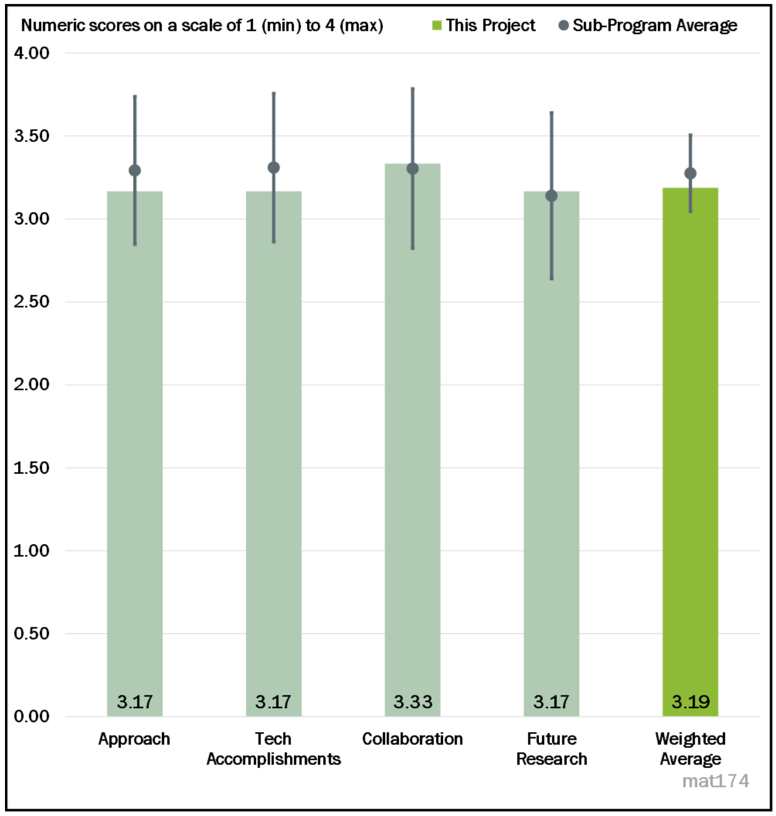

Figure 6-30 - Presentation Number: mat174 Presentation Title: Carbon-Fiber Technology Facility (CFTF) Principal Investigator: Merlin Theodore (Oak Ridge National Laboratory)

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 CFTF has been very successful. It has served as an incubator for scaling up new precursors and conversion processes. Such an approach helps remove the barriers in advancing commercialization of low cost, high performance CFs.

Reviewer 2:

The broader mission of the CFTF is not clearly delineated from the specific VTO project work. The reviewer's takeaway is that VTO funding supports the activity with mesophase pitch precursors. The effort is to work with three of five candidate materials, but it would be helpful, and improve the quality of the research, if a more explicit plan is included to interrogate other properties of the resulting blown fiber mats (including nominal fiber diameter, variance in fiber diameter, specific gravity, modulus, etc.). Finally, it is not clear if conversion to structural materials (via impregnation and cure) is planned, and more importantly, followed by testing and evaluation of those resulting composites. It is also not clear whether a path toward aligned fiber reinforcements using these candidate (or down-selected) precursors is being planned. Iit also seems important to seek out useful molecular models that can inform or predict process parameters and resulting properties to support a more rapid screening and drive future of mesophase pitch selections and designs.

Reviewer 3:
Manufacturing of carbon composites using pitch showcases the capability of the CFTF. However, it does not clearly demonstrate the facility's capability in terms of the barriers the project addressed, i.e., the cost of manufacturing, process validation and technology scalability, 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:
The team has extended the capability from polyacrylonitrile (PAN)-based pilot runs to pitch-based CFs. The CFTF has been helping academia and industry research and development (R&D) validate the recipes and scale-up.

Reviewer 2:
The team has successfully melt-blown pitch material from various sources. During blowing, multiple spinning conditions were tested, based on initial conditions suggested from rheology. Researchers demonstrated a full year of operations with zero accidents or environmental non-compliance.

Reviewer 3:
Progress includes a lot of regulatory hurdles, which the reviewer understood is necessary and meaningful, but less than technically significant. The accomplishments related to melt-blowing three of the five candidate precursors demonstrate important progress but leave many of the challenges and barriers in place and do not answer important questions related to the cost of the resulting fiber. Similarly, the referenced disadvantage vis-a-vis PAN precursors, strain to failure, and tensile strength has not been addressed as part of this year's technical accomplishments. The reviewer could not assess whether the results are promising or not.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration between the CFTF, academia, and industry partners has been going well. The CFTF has been reaching out to potential collaborators to make more impact.

Reviewer 2:
The project is very impressive, especially the collaboration between the ORNL teams: working with the analysis group on a multi-scale approach to develop optimal mechanical properties of the resultant CF from alternative precursors and working with the thermal analysis group on thermal properties.

Reviewer 3:
There is little offered that demonstrates how the collaboration (whether through the IACMI partnership or other noted collaborators) impacted the technical approach or accomplishments. It would be helpful to understand what market drivers, technical performance parameters, or specific cost targets come from the end-users or 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

Reviewer 1:
The team lays out a solid future plan. The proposed future research makes sense and the research on pitch is of great interest and is making progress toward the set milestones. The project has a thoughtful pathway to mitigating risks and removing the barriers in the way to advance scale-up and commercialization.

Reviewer 2:
The proposed future research is clearly necessary, and those specific steps make sense to the reviewer. What does not make sense is the order in which the proposed work is presented. It seems that establishing criteria should come before efforts to increase throughput, take "in situ measurements," etc. It would also be more compelling if the research team proposed specific interrogation of the produced materials in the application that is most impactful for these materials, that is, as a reinforcing element in a structural composite. No material testing is proposed toward that end.

Reviewer 3:
Completion of the pitch-based CF trial can demonstrate the capability of the facility and is important. If some new precursors and technology could be tried using the facility, it would better show the facility's capability in terms of the barriers that the project addressed, i.e., manufacturing cost, process validation, technology scalability, etc.

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

Reviewer 1:
There is no question that the mission of the CFTF and the specific work to identify alternative, low cost mesophase pitch precursors is well aligned with the stated DOE objectives. This is important work and addresses the need for affordable materials for lightweighting of future transportation systems.

Reviewer 2:
The CFTF's research activities underpin and support the overall DOE mission and, in particular, VTO objectives. The collaboration with academia and industry opens up new opportunities for scaling-up and advancing commercialization of low cost, high performance CFs.

Reviewer 3:
The facility will help speed up the development of high quality and low cost CF composites and will contribute to using lightweight materials in vehicles.

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 been extended the capability from PAN-based CFs to pitch and other alternative CFs. Such enhanced resources facilitate the scaling-up via pilot runs at the CFTF. Additionally, the CFTF leverages resources via the partnership with academia and industry.

Reviewer 2:
The facility is well equipped.

Reviewer 3:
The reviewer remarked that resources are insufficient based on the lack of progress in identifying specific work to address challenges and barriers as presented by the research team. The proposed work does not appear to address the specific concerns ("challenges and barriers") related to "availability" and "quality" of mesophase pitch feedstocks. If the goal is to produce high performance (meaning high specific stiffness and strength) materials, make sure the work being planned provides an accurate view of the status and performance of the production materials.

Presentation Number: mat175
Presentation Title: Novel Materials for Polymer Composite Engine Blocks
Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

Presenter

Amit Naskar, Oak Ridge National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

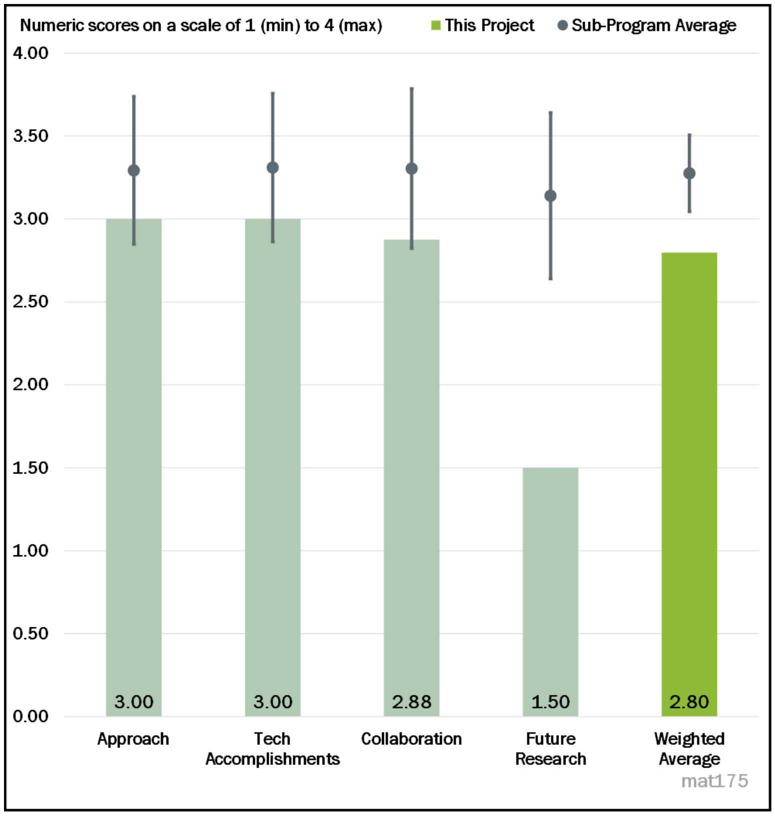

Figure 6-31 - Presentation Number: mat175 Presentation Title: Novel Materials for Polymer Composite Engine Blocks Principal Investigator: Amit Naskar (Oak Ridge National Laboratory)

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 approach appeared rational for a specific element of a larger, five-thrust program. This project was relatively narrowly designed to address a single need: development of an affordable novel polymer matrix composite with satisfactory performance for light-duty (LD) engine block applications. The overall approach regarding different chemical compositions for the base composite, as well as structural reinforcement options and bonding agents, seemed logical.

Reviewer 2:

The “co-continuous toughened resin” makes sense for toughening the composite materials.

Reviewer 3:

Overall, this is an interesting project. As a novel approach to the deployment of a new material system, however, the presentation of results was hampered to some extent by the lack of a direct correlation to common materials in engine blocks. With the stated application known at the outset of the project, the specific opportunities and potential pitfalls are lacking and were addressed in a very general state on the “Relevance” slide. More detail in this area is appropriate for work that is considered exploratory.

Reviewer 4:

It is not explained in either the presentation or the documentation why “vehicle (engine) light-weighting” would be considered a barrier. Does the project team expect the polymer blocks to be heavier? The density of Bakelite is about half that of Al, so this seems very confusing.

The resin should also have noise dampening properties superior to Al; this is not referenced but is a positive attribute of the material with data rather than just a line on the Relevance slide. Common properties from the literature would have added value to the audience. Also, on the Relevance slide, the team states "Identify technology, cost and manufacturing challenges and opportunities." However, the reviewer saw no further reference to cost in the presentation, other than stating the phenolic resins are "expensive." This really needs data as to how expensive. Once again, literature data would add a lot of 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 project achieved both of its planned technical milestones. There is a concern, however, that the project approach called for identifying cost challenges, but there was little discussion in the presentation concerning cost. When questioned, the PI indicated that the expected cost of the material would be less than $4 per pound, but that improved joining with Al would be required (implying that this might not be the ultimate cost). The PI further indicated (in response to the full question which actually asked about relative cost-competitiveness) that he could not comment on cost-effectiveness without a scaled-up investigation. Therefore, to this reviewer, that appeared to be a shortcoming, despite the accomplishment of the other project goals.

Reviewer 2:
The project achieved reasonable strength and high temperature stability.

Reviewer 3:
The microstructure-properties-performance was not necessarily completed in this project. A more application-specific milestone would have been extremely valuable to the overall study, despite its rather short timeframe, such as a cursory study of fatigue behavior at slightly elevated temperatures. Clearly, this can be a topic for future exploration, but ultimately the study was simply a correlation between several different composites and tensile strength. It could have been for any application. Delving a bit further into the engine block potential (even if only in principle) would have added a great deal of merit to the study. The development of a new interfacial engineering method was claimed, but not described in any detail. Clearly, there was a small matrix of different composites being evaluated, but what novel approach was developed is not clear from the poster.

Reviewer 4:
There are several issues previously discussed that were raised in the introduction but never explained in the presentation. The work on the acrylonitrile butadiene lignin (ABL) resin does not say if it is more economically attractive than commercial resins, although it is implied this is the case by the first bullet point on Slide 5. The ABL plus CF plus trifunctional linker (TL) tensile strength is comparable to a 356 Al (A356); this would have been great to add to the slide for reference. The mechanical properties are interesting but should have been measured at temperature (100°C, for example) to show a direct application. It would have been helpful to include a simple paper study on the carbon impact of a resin block versus Al, which is very energy intensive.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The collaboration must have been good, as the stated milestones were achieved. The role of Michigan State University is somewhat confusing, and the reviewer would like to have known what exactly was scaled up. It would appear that the results are based on labscale testing and microstructures of test specimens. Regardless, the findings being presented show a high quality set of results, both from a characterization and mechanical properties analysis standpoint. How the work was divided is not critical; the work being presented shows the proposed level of progress.

Reviewer 2:
The project was led by ORNL, with assistance from Michigan State University's SuRF to conduct the full-scale testing. The University of Tennessee is also on the team; this was due to a post-doctoral candidate who donated his hours. Overall, this was a relatively small team assembled for a tightly scoped project.

Reviewer 3:
The collaboration seems good from the project results, but it is not described in the poster presentation.

Reviewer 4:
There is no evidence that the team was or was not communicating well between members.

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

Reviewer 1:
Proposed future research is not applicable in this case, but there is a great deal of work that can be done in this area that addresses the application-specific shortcomings of an exploratory project.

Reviewer 2:
Given this is a 1-year project, that does not preclude the team from discussing the possible future of this technology and the things necessary to move this forward.

Reviewer 3:
The project has ended. The PI indicated that a scale-up project would be required, but that a partner has not been identified.

Reviewer 4:
There was no proposed future work.

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

Reviewer 1:
The project was focused on reducing vehicle weight while at least maintaining (if not improving) performance. Success would result in more fuel efficient vehicles, in line with DOE VTO objectives.

Reviewer 2:
Polymer composites are a potential lightweight engine material.

Reviewer 3:
The qualification and deployment of a new materials system in major engine components (in this case, composites) is still not a practical reality, but studies like this that show the promise are important. A great deal of work is left to be done.

Reviewer 4:
This is an interesting initiative and should have a more materials-based focus.

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

Reviewer 1:
The team successfully met its objectives and apparently did so ahead of schedule. Overall, this is a very good reflection on the team and its efforts.

Reviewer 2:
There was no indication that the limitations of the team on this work were caused by budget or resources.

Reviewer 3:
This project achieved its goal of toughening polymer composites for automotive engine applications. It reported reasonable tensile strength and temperature stability, but did not report ductility, toughness, or modulus, which would be needed for engine materials. More resources would be needed to provide a more complete answer to the challenges of polymer composites for automotive engines.

Reviewer 4:
The project has been completed.

Presentation Number: mat176
Presentation Title: Advanced Anticorrosion Coatings on Lightweight Magnesium Alloys by Atmospheric CO2 Plasma Treatment
Principal Investigator: Gyoung Gug-Jang (Oak Ridge National Laboratory)

Presenter

Gyoung Gug-Jang, Oak Ridge National Laboratory

Reviewer Sample Size

A total of seven reviewers evaluated this project.

Project Relevance and Resources

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

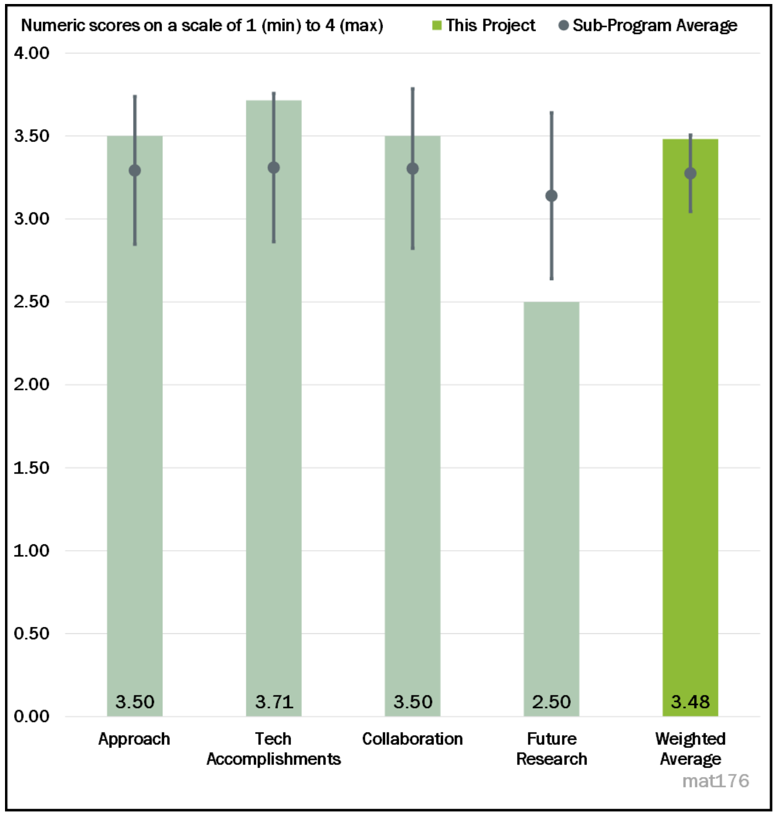

Figure 6-32 - Presentation Number: mat176 Presentation Title: Advanced Anticorrosion Coatings on Lightweight Magnesium Alloys by Atmospheric CO2 Plasma Treatment Principal Investigator: Gyoung Gug-Jang (Oak Ridge National Laboratory)

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:

This 1-year project sought to develop a cost-effective anti-corrosion treatment for Mg using room temperature CO_2 plasma. The treatment that ORNL developed forms a superhydrophobic, nano and micro-structured surface layer, which mitigates saltwater attack. This project appears to have been well planned, designed, and executed (particularly for the short 1-year project timeframe), and achieved all milestones. Generally, it was very well done. The new coating system appears to be promising in addressing the main barrier for Mg, which is corrosion. The protect team made no comment as to how this new coating technology might affect other identified barriers for Mg (maintenance, repairability, recycling).

Reviewer 2:

This project falls under Subtask 5A of the Powertrain Materials Core Program (PMCP) in Research Thrust Area 5—Exploratory research. The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent approach to use. This limits the commitment of government funding with a firm end to the project after 1 year. By completing the project in 1 year, DOE can perform the assessment of potential materials using this cost effective approach. Where applicable, other research programs should consider replicating this approach.

The project was a 1-year assessment, completed March 2020. DOE's share of this project was $150,000, and there was a cost share of $7,500 by Atmospheric Plasma Solutions (APS). All milestones for this project were achieved.

Mg has poor corrosion resistance; the goal was to demonstrate an advanced, anti-corrosion coating treatment using carbon dioxide (CO_2) chemical plasma techniques. This is important where Mg is joined with steel.

Reviewer 3:
Atmospheric CO_2 plasma is a potential coating process to improve the corrosion resistance of Mg alloys, solving a long standing problem with Mg applications.

Reviewer 4:
The approach appears to be sound. The technique of subjecting a cast Mg part to a CO_2 plasma to create a carbonate, magnesium carbonate ($MgCO_3$), and magnesium oxide (MgO) surface layer appears to be new.

Reviewer 5:
While the primary focus of the work seemed to focus on pure Mg, which has little to no interest for structural applications, the team showed that the application to a structural material, AZ31b, (was not as easy as working with pure Mg. It was difficult to access the relative focus on pure versus structural Mg alloys, but for an exploratory project, the evaluation of the process on the material was excellent.

Reviewer 6:
The approach to performing the work was appropriate to the project objectives. The work follows closely to a 2018 *Nature Communications* journal article by Wang and co-workers which utilized excited CO_2 to modify magnesium oxide (MgO) to magnesium carbonate ($MgCO_3$). This project scaled up the work into sheet form through the utilization of a CO_2 plasma. Two aspects which were not addressed were the broader commercial feasibility of treating large Mg sheets with plasma CO_2, and the use of plasma CO_2 on non-planar geometries.

Reviewer 7:
The project successfully demonstrated the proposed concept. The project included surface modifications and preliminary corrosion testing. Approach of the work was clearly laid out and the tasks were appropriate to accomplish the project goals. The results show improvement in the corrosion performance of the treated parts as compared to the untreated ones.

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 performer made excellent progress in this 1-year effort. The project was successfully completed, and all of the milestones were either achieved or exceeded. The demonstrated reduction in corrosion rate was impressive; several orders of magnitude compared to the untreated baseline.

Reviewer 2:
The project was successfully concluded and met all of its technical objectives. The reviewer would like to know if the part needs to be cleaned prior to the plasma treatment, and if the plasma treatment cover all of the surface for parts with a significant surface area.

Reviewer 3:
The project specifically focuses on the primary problems with Mg alloys. While the project had only a small focus on Mg alloys, it clearly evaluated the influence of the $C0_2$-atmospheric plasma ($C0_2$-AP) treatment on pure Mg, which may open opportunities to more effectively apply a similar treatment to structural alloys.

Reviewer 4:
The project demonstrated a significant improvement of corrosion resistance in AZ31 sheet, but did not try the AZ91 magnesium alloy or magnesium AM60 castings.

Reviewer 5:
By using the CO_2 chemical plasma technique, a corrosion resistant coating of MgO and MgCO3 was formed. This treatment significantly reduced the corrosion rate of the CO_2 treated version and untreated Mg and Mg alloys (AZ31B). This treatment also creates a surface layer that has super-hydrophobicity, repelling water and mitigating salt water effects. By using the CO_2 plasma, carbon is well distributed into the dense surface layer of carbonate, $MgCO_3$, and MgO (MgO adsorbs CO_2 to get $MgCO_3$). This was confirmed by both the high annular dark field scanning transmission electron microscopy (HAADF-STEM) with energy-dispersive X-ray (EDX) elemental mapping and X-ray photo electron spectroscopy (XPS).

Reviewer 6:
This was a single year proof of concept project. In that regard, the PIs successfully delivered by demonstrating the formation of a protective layer on the magnesium metal surface by plasma treatment. Further, limited corrosion tests showed the performance improvements. The next barrier for this technology is to optimize the process and develop its performance boundaries.

Reviewer 7:
The project had well focused technical experiments addressing the project objectives in a meaningful and efficient manner.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
As this was a smaller project, little collaboration was required. However, ORNL did show the ability to acquire specimens from team members to facilitate rigorous evaluation.

Reviewer 2:
This was a very nice example of a public-private collaboration, with well-defined roles and coordination. The commercial partner, APS, treated the Mg specimens under different CO_2 plasma operation conditions, while ORNL led the scientific effort and performed testing and evaluation.

Reviewer 3:
The project results indicate good collaboration between the project partners.

Reviewer 4:
Close collaboration with the industrial partner, APS, created meaningful results.

Reviewer 5:
The ORNL project team worked closely with APS, the industry partner, to determine the feasibility of CO_2 plasma treatment on Mg. No other partner was included, however, for this work, and it will be shared with the other project activities under Subtask 5A of the PMCP in Research Thrust Area 5: Exploratory research. The PMCP umbrella is a low-cost approach to coordinating interconnected research.

Reviewer 6:
There was a commercial partner on the project that provided cost share in terms of in-kind work. The partner performed the plasma treatment of the samples.

Reviewer 7:
It was not clear from the presentation what APS Incorporated contributed to 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

Reviewer 1:
This is a 1-year project with no future work planned. However, there were some suggested future developments on Slide 9. The reviewer would like to have known more about Mg AZ61, Mg AZ91, and rare-earth-bearing Mg alloys. Specifically, the reviewer wanted to know if the plasma treatment will work, and if the CO_2 treatment could be applied to in-line manufacturing of a wrought Mg sheet. One of the corrosion mechanisms is the hydrogen evolution reaction at the transition of metal particles and precipitates that work their way to the surface of the Mg.

Reviewer 2:
The reviewer stated this is not applicable since the project is complete. Next steps will involve investigating additional operational conditions and exploring feasibility as part of a multi-layer coating protection scheme, which seems sensible.

Reviewer 3:
Future efforts could focus on multi-layer coatings or an assessment of changes in physical characteristics caused by the coating. Also, plasma application cost estimates should be performed to determine if this approach is an economically viable approach to develop an anti-corrosion solution for Mg. If this process is deemed cost effective, common automotive Mg alloys should be assessed for anti-corrosion coating formation by using the CO_2 plasma.

Reviewer 4:
The future work needs to address the mainstream Mg applications (AZ91 or AM60 castings with complex geometries).

Reviewer 5:
The project ended in March 2020 and the presenter indicated that the project was 100% complete.

Reviewer 6:
The project was completed.

Reviewer 7:
The project ended.

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

Reviewer 1:
This is good to see that DOE is providing funding that is somewhat beyond the scope of current OEMs' focus. The success of this and other work may open doors for OEMs to reevaluate the use of Mg alloys in future vehicles.

Reviewer 2:
This project seeks to address some of the technical barriers associated with increased deployment of lightweight Mg in vehicles. This project is consistent with DOE's vehicle lightweighting objectives.

Reviewer 3:
Scalable corrosion protection methodologies on lightweight alloys, especially Mg-based alloys, supports DOE's overall objectives.

Reviewer 4:
Yes, this project supports DOE's overall objectives by providing the knowledge needed to develop high performance materials for lower cost, higher efficiency engines and vehicles.

Reviewer 5:
The project supports DOE's objectives for vehicle lightweighting by overcoming challenges with low density materials such as Mg.

Reviewer 6:
Mg is an important lightweight material.

Reviewer 7:
The reviewer referenced prior comments.

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

Reviewer 1:
This project was experimental in nature and all of the right tools were applied.

Reviewer 2:
The project appeared to be a well-balanced, well-funded exploratory effort.

Reviewer 3:
Resources were sufficient. ORNL had the laboratory-scale resources required and collaborated with a commercial partner to gain additional expertise and capabilities for the plasma treatment aspect of the project. The project was completed on time.

Reviewer 4:
The entire project and project milestones were completed in a timely fashion with sufficient resources to meet project objectives.

Reviewer 5:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 6:
The resources for the project were adequate for achieving the milestones.

Reviewer 7:
This coating is supposed to be low cost.

Presentation Number: mat177
Presentation Title: Novel Aluminum Matrix Composite for Powertrain Applications
Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

Presenter

Zhili Feng, Oak Ridge National Laboratory

Reviewer Sample Size

A total of six reviewers evaluated this project.

Project Relevance and Resources

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

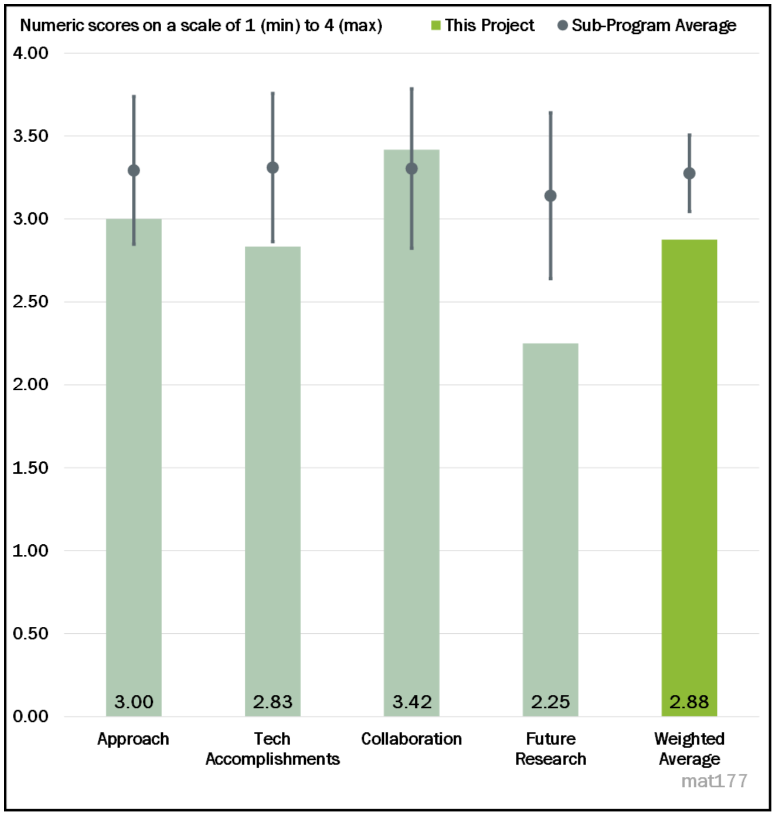

Figure 6-33 - Presentation Number: mat177 Presentation Title: Novel Aluminum Matrix Composite for Powertrain Applications Principal Investigator: Zhili Feng (Oak Ridge National Laboratory)

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:

While the overall approach to the fabrication of the specimens is excellent (a definition is provided on the use of solid state processing to overcome limitations of casting), the milestone for the project was a 20% increase in strength at both room temperature (RT) and at 300°C. The project only showed a focus on microhardness at RT, which is assumed to increase when harder materials like carbon and intermetallics are embedded. There is ample literature related to friction stir processing (FSP) that suggests a correlation between microhardness and strength is not linear when embedding products much harder than the base materials. As such, the evaluation of strength by means of microhardness is a significant inadequacy of the presented approach.

Reviewer 2:

Regarding Al matrix composite, the reviewer stated improving strength and greater than 20% weight reduction at RT and 300°C. The technical approach of using FSP does overcome the challenges of producing castings with uniform nanoparticle dispersions. However, the reviewer was not sure if FSP is applicable to the complex geometries of the target applications: turbo compressor housings, cylinder heads, compressor wheels, and pistons. Perhaps FSP is applicable to local strengthening, but the reviewer was not certain if that would be sufficient and cost effective for automotive applications. The reviewer would also like to have known if hardness measurements directly correlate to strength and had a concern over defects that affect strength but that will not show up in microhardness testing. Strength was listed as the primary milestone, but the reviewer did not see any strength testing results.

Reviewer 3:
This exploratory research project aimed to develop new, high strength Al matrix composite (AMC) alloys. The performer's approach was to use solid state processing technologies (FSP and friction stir extrusion [FSE]) to develop the new alloys, and multi component additives such as graphene and carbon, carbide, oxide particles, and intermetallics were incorporated to enhance the material strength. The solid state processing approach seems promising, and ORNL was able to demonstrate the synthesis of a fully consolidated block of an FSP-produced Al composite. This is good; however, the reviewer thought the characterization of the new material could have been somewhat more thorough and responsive to the performance targets. For example, it is still unclear how the mechanical strength of the new material compares to the baseline alloys, since the project team apparently only measured the hardness.

Reviewer 4:
Al-based metal-matrix composite (MMC) materials can potentially be used in cylinder liners, pistons, driveshafts, and connecting rods. Powder metallurgy and mechanical alloying is an expensive process.

Reviewer 5:
This project falls underSubtask 5C of PCMC in Research Thrust Area 5—Exploratory research. The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is excellent. This limits the commitment of government funding with a firm end to the project after 1 year. By completing the project in 1 year, DOE can perform the assessment of potential materials using this cost effective approach. Where applicable, other research programs should consider replicating this approach.

This project ended May 2020, a 1-year assessment. The ORNL budget for this effort was $100,000 (note: PNNL has a parallel effort to investigate different dispersion additives and is also funded at $100,000).

The purpose of this project was to further increase the high temperature strengths of best in class powertrain and body structure Al alloys. Methods under consideration include strengthening of solid solutions; hardening of precipitations and aging (currently used to achieve high strength Al alloys); and dispersion strengthening via mechanical alloying.

The project investigated using the third approach (dispersion strengthening via mechanical alloying) to create Al matrix composites). This approach adds thermally stable, nearly insoluble, and very low diffusivity oxides and other dispersoids to develop the matrix composites. Target applications for this material include a variety of powertrain applications and feedstock materials for additive manufacturing (AM).

The milestone for this project is to develop and validate an Al matrix composite material with an increase in strength greater than 20% at both RT and 300°C, compared to the baseline 7xxx series alloys or cast ACZM alloys. To accomplish this milestone, the researchers used the solid state processes of FSP and FSE to create these composite matrices. Additives considered included graphene and carbon, and nano additives of carbide, oxide particles, and intermetallics.

Reviewer 6:
The approach was to develop MMCs using solid state processing by incorporating second phase reinforcements. The PIs were able to successfully disperse the reinforcements in the metal matrix. However, the overall quality of the MMCs is not clear since the property measurement made was hardness, which is a fairly localized characterization. If some of the bulk mechanical property was reported, it would provide a better picture of the overall material developed.

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:
As referenced in prior comments, the objective was to develop Al alloys with increased high temperature (HT) behavior. However, the results reported are only for ambient conditions hardness. It would have been really nice to see the strength data at ambient conditions and at elevated temperatures. The outcome of the project is successful dispersion of the reinforcements in the metal using solid state processing with demonstrated hardness enhancements.

Reviewer 2:
Considering the short, 1-year timeline, the performer made acceptable progress. However, the key project milestone was a mechanical strength increase, whereas the performer measured hardness. It would have been helpful to see results from conventional strength tests. The assessment method chosen (indentation microhardness) is a localized test method that probes only a few millimeters, maximum, into the surface. It may not give an accurate sense of the general or bulk properties of the material, which will be key in the structural applications targeted. The reviewer also does not see any evidence of measurements at elevated temperatures (which had been another project milestone).

Reviewer 3:
The project only reported microhardness data. No other properties were tested.

Reviewer 4:
The project set out to demonstrate a strength increase at both RT and at 300°C. At 85% complete, the project team has shown none of the following: evaluation of material at temperature; evaluation of properties beyond microhardness; or plan to do anything beyond evaluate heat treatment. The reviewer, therefore, cannot find a plan or progress toward the goals specified in the work and milestones shown for this project. The team did make significant work at fully densifying the FSP product, which is a commendable start.

Reviewer 5:
The reviewer did not see any strength testing or any testing at 300°C. Both of these were primary objectives, so it does not appear that accomplishments met the project goals. The project was to be completed May 2020. The presentation says it is 85% complete, but no explanation on schedule changes was given.

Reviewer 6:
The researchers created Al composite matrices for mechanical property testing using AA6061 and AA7075 as the baseline material, and then integrated the additives using the solid state friction processes. The matrix materials included the additives carbon and intermetallics, and silicon carbide (SiC) at 3%-10% weight.

The matrix composites developed included 6061 matrices with two different additives. Up to a 25% increase in microhardness was achieved by adding intermetallics and SiC particles, and the solid state processing resulted in a uniform distribution of intermetallic particles.

The matrix composites developed using 7075 baseline as the material added carbon and intermetallics. Up to a 50% increase in microhardness with a 5% weight intermetallic additive was achieved. A 15% increase in microhardness with a 3% carbon weight was also achieved.

Heat treatment was applied to both matrices to the temper 6 (T6) level achieved a 20%-30% improvement.

The reviewer noted that the PI did not answer the questions. Several outcomes from this research are unclear, although he did indicate that the project successfully demonstrated the feasibility of solid state material processing with mechanical alloying to synthesize stronger and lighter Al metal composite materials for engine and body structures. The reviewer believes that this project did accomplish this goal, and that mechanical alloying through solid state processing should be considered when developing new material matrices.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was excellent coordination with the PNNL processing team.

Reviewer 2:
The collaboration with PNNL seems appropriate, as each laboratory has unique processing capabilities. Coordination between laboratories was good. Being that unique alloys were shared, however, all evaluation presented herein seems to be in AA6061 and AA7075.

Reviewer 3:
The project was conducted at ORNL and regular collaboration discussions occurred with PNNL.

Reviewer 4:
This was mainly a parallel effort between the two laboratories. Collaboration included frequent conference calls and web meetings, but it looks like work was largely done separately. There was some material sharing.

Reviewer 5:
Several related projects are being performed in parallel since this is part of the PMCP. For this activity, a parallel research activity is occurring at PNNL, which is focused on ShAPE processing. Laboratories have frequent conference calls and web meetings to coordinate on materials and additives (e.g., ORNL provided the ACMZ alloy to PNNL).

Reviewer 6:
The project shows good collaboration among several partners.

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

Reviewer 1:
The proposed future work (the remaining work for this effort) seems to miss the mark in achieving the milestone documented in this presentation. Mechanical properties do not linearly correspond to microhardness for FSP samples with additives much harder than the base material. While students at universities may use this tactic because of a limitation on batch size of material to test, the objective of this study was to produce a sufficient quantity of materials to evaluate properties—rather than microhardness alone—and no plan is presented to actually do that with the funding provided.

Reviewer 2:
The project appears to have ended. Proposed future research is on post process heat treatment and completing microstructure, mechanical property, and functional property characterization. It was unclear if all of that was going to be done under this project or a future project.

Reviewer 3:
The project has ended.

Reviewer 4:
The reviewer hopes to see more properties tested as planned in the future work.

Reviewer 5:
The project ended, and it was a 1-year year project.

Reviewer 6:
The reviewer believes the project has ended, but the PI did not confirm. Several companies have expressed interest in this activity and taking the results forward. Specifically, General Motors (GM), Powertrain, Magna and Cosma, and Ford have all expressed interest. For future research, the PI proposed completing a heat treatment study of the matrices for the T6 and T651 conditions. Other proposed future work included assessing the microstructure as well as the mechanical and functional properties of these matrices.

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

Reviewer 1:
The project has excellent alignment with DOE's goals of achieving decreased carbon emissions and improving fuel economy with better engineered material performance. The reviewer applauds the foresight to reach beyond traditional processing methodologies to enable lighter and stronger powertrain materials.

Reviewer 2:
Improved materials are essential for new technology to improve fuel efficiency or extend the range of EVs.

Reviewer 3:
This project, focused on the development of higher strength structural Al alloys, is consistent with DOE's vehicle lightweighting objectives.

Reviewer 4:
Yes, this project supports DOE's overall objectives by providing the knowledge needed to develop high performance materials for lower costs and higher efficiency engines and vehicles.

Reviewer 5:
DOE's objective is reducing fuel consumption and vehicle weight. In this regard, the project addresses the need to develop high strength, lightweight alloys that can operate at higher temperatures.

Reviewer 6:
Al-based MMCs could play an important role in some engine applications. The key is to reduce the cost. The material and process combinations in the current project seem expensive.

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 have been sufficient.

Reviewer 2:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 3:
Resources at both ORNL and PNNL were available and sufficient for the project.

Reviewer 4:
The project seems to be behind, perhaps due to COVID-19.

Reviewer 5:
The resources provided were sufficient for the tasks at hand; however, the team seems to have been distracted from the actual goals of the work.

Reviewer 6:

It does appear that all of the milestones have been achieved to date. The reviewer commented that 85% of the budget to produce samples and conduct harness testing appears to be excessive.

Presentation Number: mat179
Presentation Title: Development of High-Temperature Sample Environment for Advanced Alloy Characterization Utilizing High-Speed, Micron-Resolution X-Ray Imaging Techniques
Principal Investigator: Dileep Singh (Argonne National Laboratory)

Presenter

Chih-pin “Andrew” Chuang, Argonne National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

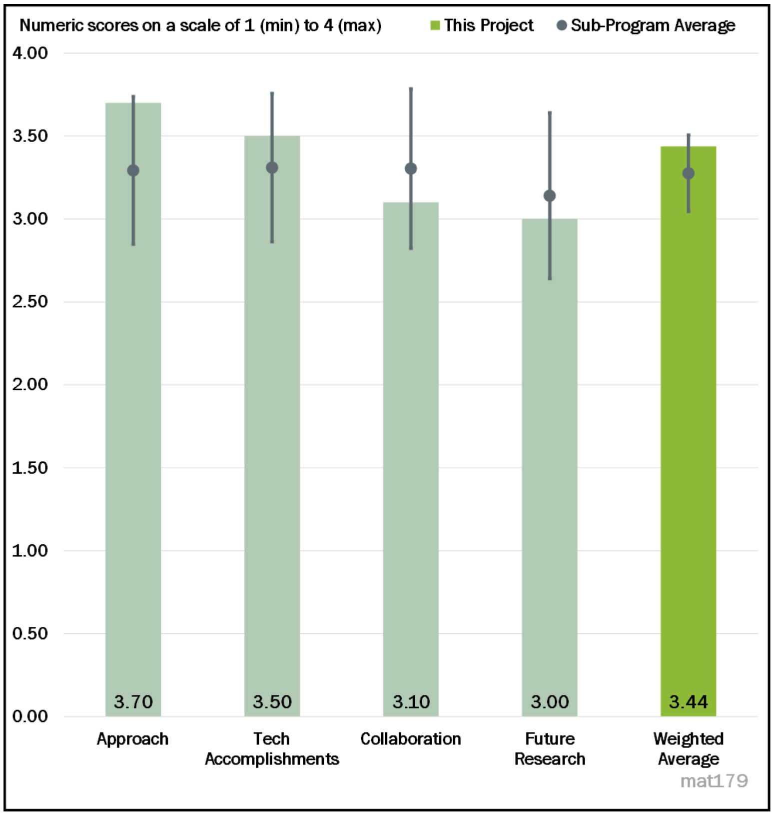

Figure 6-34 - Presentation Number: mat179 Presentation Title: Development of High-Temperature Sample Environment for Advanced Alloy Characterization Utilizing High-Speed, Micron-Resolution X-Ray Imaging Techniques Principal Investigator: Dileep Singh

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 is a well done, nice piece of work, and it is great to add this capability. The use of induction heating to decrease local thermal loading was a great idea. The rapid heating and cooling are important to prevent grain growth and look at transformation mechanics.

Reviewer 2:
The approach for the project appears well thought out and logical for this relatively specifically targeted project. The team appears to have studied current testing environments in detail and designed this project to overcome the shortcomings of existing approaches. In particular, the focus on induction heating not only targets key shortcomings, but also takes advantage of a rapidly improving technology. In addition, the use of a susceptor to achieve temperature uniformity appears to have been a key decision.

Reviewer 3:
With a focus on designing, building, and testing a sample environment that can be utilized with the synchrotron, the team seemed to stay focused on providing an environment and control that could be used in the spatial and environmental constraints of the facility.

Reviewer 4:
The method is robust, and the equipment has been well designed to provide the needed information.

Reviewer 5:
The work is very useful and potentially has a very high impact.

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 well scoped project that clearly met all of the initial intentions of the work.

Reviewer 2:
The project appears to have achieved its technical milestones of developing a system capable of reaching stable, higher temperatures, and completing experiments at temperatures significantly above currently available levels. Therefore, a proof of concept has been completed. The team is still waiting on another material sample that should offer an opportunity for conducting even higher temperature experiments.

Reviewer 3:
The teams seem to have been able to accomplish all of the directives that were setup to accomplish.

Reviewer 4:
The reviewer would like to see a more quantitative assessment of the capability for various types of materials and suggests showing at what accuracy the team reached the desired temperature and the error in the temperature measurement.

Reviewer 5:
Slide 4 talks about very high resolutions, but the reviewer cannot tell if these resolutions were accomplished by looking at Slide 7. Slide 8 discusses two user experiments that were conducted. The reviewer suggests that the project team provide this imaging and temperature data because it is difficult to appropriately rank the progress without this information. In addition, the reviewer would like to know if the temperature data in Slide 6 is from these experiments or a generic experiment. The reviewer is not concerned that ambitious values of imaging or temperature profiles were not obtained, but rather what was indeed obtained.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer does not think this was an issue, given that all of the project scientists were in the Applied Materials Division at ANL.

Reviewer 2:
While the project itself was designed to be completed by a team solely from ANL, the team did work with two user groups- one from MINES Saint-Étienne, France, and the other from the California Institute of Technology. These organizations had testing needs which matched the new system's capabilities, and thus assisted in validating the operation by participating in testing.

Reviewer 3:
While collaboration exists, there was little that was presented showing the benefits of the collaboration to the current work.

Reviewer 4:
It appears that the collaborators have provided the problems and that the experiments are in progress. Conversely, it is that the "Status" is related to work done with the collaborators? For example, does the comment "Conducted two user experiments" mean that the experiments were related to the two collaborators? Some details would be helpful.

Reviewer 5:
Collaboration seems good.

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

Reviewer 1:
Adding a load frame to the system to characterize the material under load at an elevated temperature is a good future enhancement. Quenching would also be a great feature.

Reviewer 2:
The project is effectively over, with only a few remaining activities to be completed that had been delayed. The team has identified activities for future research to further improve the system.

Reviewer 3:
The reviewer is not clear how the proposed future research connects with the problems of the two collaborators. The engineering purpose of the work is not clear. What will this unit provide in terms of understanding certain mechanisms? What is the contrast mechanism for recovery and recrystallization in a tomography unit?

What mechanisms will heating and cooling tell the project team at a 0.5 um resolution? Have the authors considered using this equipment for sintering studies or for looking at damage during high temperature deformation?

While the technique is extremely ambitious and challenging, the use of the equipment regardless of where we land on its capability should be detailed better.

Reviewer 4:
The reviewer indicated no comments.

Reviewer 5:
The reviewer indicated no comments.

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

Reviewer 1:
This project supports the goal of using synchrotron X-ray techniques for material characterization to facilitate powertrain materials research as the market demands lower carbon emissions and higher power density.

Reviewer 2:
The purpose of the project is to increase the temperature testing capability for materials in order to accurately characterize the properties and performance of advanced materials that can contribute to increased efficiency.

Reviewer 3:
This work is highly relevant to DOE objectives and will hopefully enable future characterization that is beyond the current capabilities. An excellent direction and goals for the overall scope have been defined.

Reviewer 4:
If the time of HT materials processing can be shortened, then it will greatly add to energy reduction and missions.

Reviewer 5:
This project is very supportive, as it can enable HT, in situ experiments.

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

Reviewer 1:
This is a well-done project on a small budget. Nice work.

Reviewer 2:
The project appears to be staffed by very capable people.

Reviewer 3:
Resources appear sufficient and the project is nearly complete.

Reviewer 4:
While the setup and control could have been done for much less, the integration with an X-ray source sufficiently complicates the work to justify the resources.

Reviewer 5:
Resources are good.

Presentation Number: mat180
Presentation Title: Reducing The Weight of Vehicle Components via Lost-Foam Casting of Ductile and Austempered Ductile Iron
Principal Investigator: Sarah Jordan (Skuld)

Presenter

Sarah Jordan, Skuld

Reviewer Sample Size

A total of three reviewers evaluated this project.

Project Relevance and Resources

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

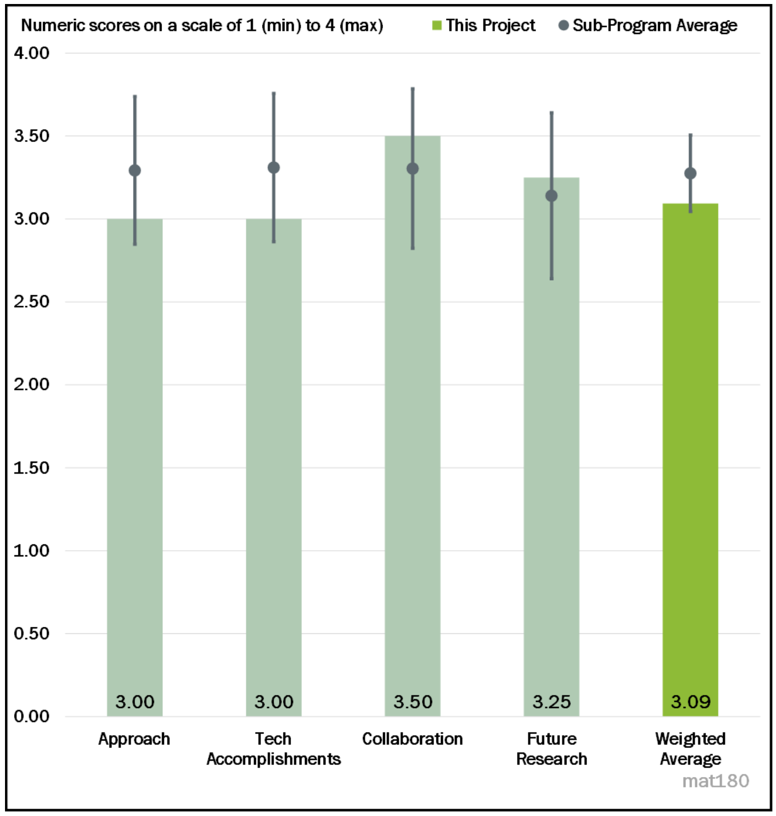

Figure 6-35 - Presentation Number: mat180 Presentation Title: Reducing The Weight of Vehicle Components via Lost-Foam Casting of Ductile and Austempered Ductile Iron Principal Investigator: Sarah Jordan (Skuld)

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 developing thin wall ductile Fe components using lost foam casting appears to be feasible. The project is straight forward and well designed, but the lack of a larger scale furnace for casting heats appeared to hinder progress, and thus the project has not been able to demonstrate full industrial viability. Since the company has a long history in making thin wall ductile Fe, it is no surprise that this project has seen reasonable success.

Reviewer 2:

It seems that this project is partially complete at this point, but the reviewer is not sure if the project will meet the stated deliverables by the end of June 2020. Technical barriers have been partially addressed. For example, the reviewer would like to know if it has been demonstrated that the lost foam casting process will lead to 1-mm thick ductile Fe castings that are largely defect free.

Reviewer 3:

The approach for the project was well laid out. Key technical barriers and metrics for the success were well defined. Specific characterizations that were needed were also outlined.

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 made significant progress toward demonstrating the feasibility of thin walled ductile Fe castings. Various tests were conducted, including microstructure, surface roughness, nodule count, fluidity, etc., to show that the casting can be fabricated. However, it would have been nice to see some mechanical property data. The project did demonstrate elimination of massive carbides for thin wall castings, which is an excellent progress.

Reviewer 2:
This project has some lofty and certainly laudable technical plans. Progress has been good, but it seems that the project is only partially completed. The project has demonstrated reduced and eliminated massive carbide defects in castings as thin as 1.8 mm, but the reviewer would like to have known if defect free lost foam castings at a nominal thickness of 1 mm were produced. In addition, it is unclear if the proposed lost foam casting process is a high volume production process or if it is limited to the small-scale production of parts.

Reviewer 3:
Two of the three identified objectives have successfully been demonstrated. A laboratory-scale demonstration of thin wall cast ductile Fe with dimensional control within 5% illustrates satisfactory progress.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaborations with the main subcontractors appear to be strong; however, collaborations with automotive manufacturers would strengthen the work.

Reviewer 2:
The project was very well coordinated with The Ohio State University, Worcester Polytechnic Institute (WPI), etc.

Reviewer 3:
Collaboration with Ohio State and WPI has provided non-redundant and critical contributions to the project regarding laboratory-scale casting production and surface roughness measurements. The surface metrology approach seems standard. Surface roughness (Ra) is not a good indicator of surface functionality, and the reviewer would like to know what functional aspects of the surface need to be controlled (e.g., appearance, lubricant transport, etc.). It seems to be purely appearance controlled (i.e., no Styrofoam cup topography?).

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

Reviewer 1:
Although this was a 1-year, Phase 1 project, the PIs have laid out a well-defined plan for Phase 2.

Reviewer 2:
A brief outline of the predictive model would help. Also, process control ranges need to be established. It seems like this will require more than just Calphad modeling, (e.g., it will need to couple heat transfer, fluid flow, microstructure evolution during solidification, and defect nucleation). It seems that this might be way beyond the scope of this project, and the reviewer would like answers to the following questions:

- Will this part of the project be developed at Ohio State?
- Is lost foam more costly than other part casting processes?

- How much cost will the coating add to the lost foam process?
- Will the cost for mass produced (e.g. millions per year) parts outweigh the potential benefits?
- Does the X-ray radiography have a high enough resolution to detect the range of porosity that would impact pat performance?

Reviewer 3:
The future research outlined is appropriate given the results obtained in Phase I of the research. The predictive modeling efforts and large-scale production are the strongest endeavors. However, the modeling efforts will depend on a strong dataset for input parameters. It is unclear where the fundamental data that will be integrated will come from, and if it will ultimately validate the models.

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

Reviewer 1:
Weight (mass) reduction of cast parts is critical for automotive applications.

Reviewer 2:
Yes, thin wall sections of high strength metals in automotive components significantly contributes to DOE's lightweighting initiatives.

Reviewer 3:
Thin walled ductile Fe castings without massive brittle carbides will allow the use of Fe-based castings for various vehicle components. Clearly, using thin walled, high strength materials will lead to vehicle weight reductions, and consequently, significant fuel savings.

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

Reviewer 1:
Yes, the resources were commensurate to the project tasks.

Reviewer 2:
Resources are sufficient for now, but it is unclear if adequate resources are available to finish the project, especially the development of the predictive model from casting to part performance in a vehicle assembly.

Reviewer 3:
Resources appear to be sufficient given the stated objectives. The only resource that was lacking was a production-scale furnace. However, this will be addressed in future research.

Presentation Number: mat182
Presentation Title: High-Strength Aluminum-Graphene Composite for Powertrain System
Principal Investigator: Xiao Li (Pacific Northwest National Laboratory)

Presenter

Xiao Li, Pacific Northwest National Laboratory

Reviewer Sample Size

A total of four reviewers evaluated this project.

Project Relevance and Resources

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

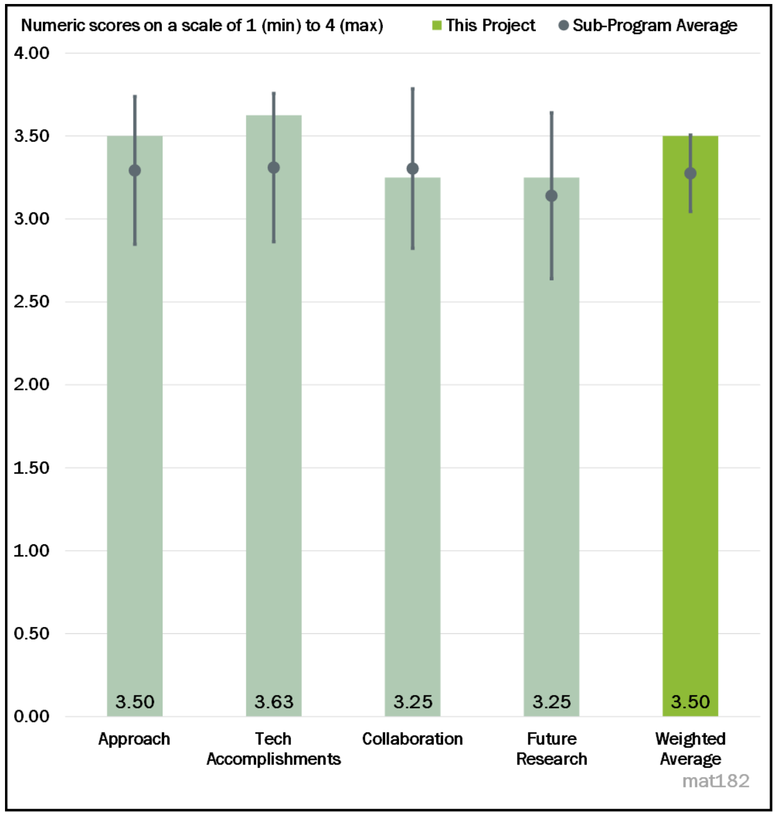

Figure 6-36 - Presentation Number: mat182 - Presentation Title: High-Strength Aluminum-Graphene Composite for Powertrain System Principal Investigator: Xiao Li (Pacific Northwest National Laboratory)

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 performer used the ShAPE process to produce an Al-graphene composite. This material system is promising due to its outstanding toughness and fatigue strength; however, two main technical barriers are segregation (caused by the combination of density differences between the metal and graphene, and poor mixing) and overheating (formation of weak intermetallics and low quality composite caused by excessive processing temperatures). The project team did a nice job clearly explaining the barriers and how the ShAPE technique could address them through enhanced mixing and low temperature processing. There are still some potential concerns about scalability for this manufacturing technique that will need to be addressed in the future; however, for an early stage exploratory effort, this appears to have been a well planned and executed study.

Reviewer 2:

The project involved using solid state mixing of particulates and reinforcements in Al alloys to enhance the mechanical properties. The project uses ShAPE technology that allows mixing of the reinforcements in the alloy and extrusion of the composite in wire form. The project was well designed, with key steps clearly outlined. The approach adequately addressed the technical barriers.

Reviewer 3:

There is a well-developed approach using the pre-existing ShAPE process at PNNL.

Reviewer 4:
The use of ShAPE is a novel way of incorporating graphene into Al to form a composite.

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:
There were two milestones in this 1-year effort, and both were met or exceeded (the project has now ended). The first was to produce a void-free aluminum graphene composite (AGC) with uniform dispersion. The second was to improve mechanical properties by 15% at room temperature and at 300°C. The first milestone was met. The second milestone was substantially exceeded, with a demonstrated increase of 40%-100% in strength. This was a very successful project.

Reviewer 2:
The project accomplished two key objectives: (a) a void free composite with reinforcements dispersed and (b) a greater than 15% improvement in mechanical properties at room temperature and at 300°C. The progress made in the project has been outstanding for a 1-year exploratory project. There are additional targets that the PIs have proposed for future work.

Reviewer 3:
The composite material properties were considerably improved and exceeded the targets.

Reviewer 4:
The team achieved alloy development with well mixed aluminum and graphene and a backwards extrusion pressure under high temperatures and pressures (using ShAPE). The alloy has a uniform nanostructure and a processing temperature below 450°C. Brittle intermetallics and melting segregation are avoided. The reviewer would like to know if the proposed Al and graphene material is limited to Al7075.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was outstanding collaboration with staff at PNNL and ORNL in terms of producing the alloy and characterization.

Reviewer 2:
This was mainly a parallel effort between the two laboratories. Collaboration included conference calls and web meetings, but it looks like work was largely done separately. There was some material sharing.

Reviewer 3:
It seems that ORNL provided some cast materials, but the reviewer would like to know what else ORNL contributed to the project.

Reviewer 4:
The reviewer could not tell which part of the work was conducted at ORNL. The ShAPE equipment is at PNNL, so the reviewer expects that ORNL conducted some of the characterization.

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

Reviewer 1:
The reviewer agreed that the next step is to scale up to a larger diameter stock. The 0.1 inch diameter wire is good for a proof of concept but would need to be much larger to make production parts.

Reviewer 2:
The project has ended.

Reviewer 3:
The project has ended and the PI notes that there may still be an opportunity for improvement, as the theoretical yield strength of the AGC has not yet been achieved. In addition, the extrusion speed needs to be increased to meet industrial demands. The wire diameter will also need to be increased to create full size components.

Reviewer 4:
This process is interesting but likely will be very costly once scaled up to make commercial parts for the automotive industry, for example. Adding heat adds cost, meaning there is a costly Al alloy (7075), with a costly additive (graphene), combined with a costly manufacturing process (ShAPE). The reviewer wants to know if the project team has explored high speed rotational casting, if the team has focused on less costly Al 6xxx alloys, and if the addition of graphene will mitigate 7075 corrosion. It seems that scaling up the current wire extrusion process will require substantial manufacturing complexity and cost. In addition, the reviewer wonders if the mechanical property benefits of as-produced Al-graphene alloys outweigh the manufacturing and material costs, and if it can compete with processes such as 3-D printing for powertrain components which are currently the subject of enormous attention. Lastly, the reviewer questioned if the team can partner with a company that is directly involved in making powertrain components for the automotive industry. It seems that this could give the project much direction and focus.

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

Reviewer 1:
The project is related to the development of lightweight Al alloys with improved mechanical performance at elevated temperatures. Successful demonstration can lead to use of the alloys for engine components to allow operation at high temperature for higher fuel efficiency and reduced vehicle weight.

Reviewer 2:
This project supports the DOE lightweighting objectives for transportation.

Reviewer 3:
This project, focused on development of higher-strength structural Al alloys, is consistent with DOE's vehicle lightweighting objectives.

Reviewer 4:
This project does support the DOE objective of improved fuel economy by lightweighting.

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

Reviewer 1:
Resources appear to have been sufficient.

Reviewer 2:
This was a 1-year project and the teams in place were able to reach the objective.

Reviewer 3:
Resources at both PNNL and ORNL were sufficient and available. The ShAPE processing equipment was available to the project.

Reviewer 4:
Resources seem sufficient, but the reviewer would like to know if ORNL contribute more in the future.

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 three reviewers evaluated this project.

Project Relevance and Resources

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

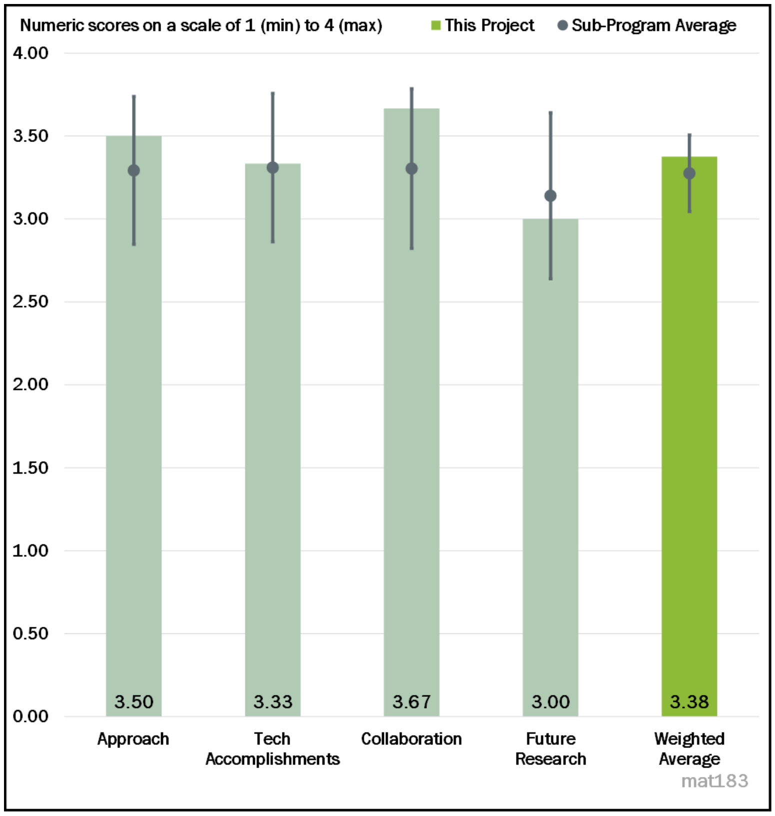

Figure 6-37 - Presentation Number: mat183 Presentation Title: High-Temperature Coatings for Valve Alloys Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

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:

There is a great use of modeling and experimental work in the plan.

Reviewer 2:

This reviewer referenced Subtask 2A3—High-Temperature Coatings for Valve Alloys within the PMCP of Research Thrust Area 2—Cost Effective Higher Temperature Engine Alloys, Some additional funding is provided under Subtask 4B – Advanced Computation of Research Thrust Area 4B—Advanced Computation under the PMCP. The approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent approach to use.

The reviewer reported that the fiscal year (FY) 2020 budget was $197,500 (subtask 2A3 funding was $175,000 and subtask 4B funding was $22,500). Additionally, this is a 5-year (2018-2023) activity, and the period of performance is 30% complete. The project aligns with the PMCP timeline.

The goal of the project is to enable lower cost, higher strength alloys for valve operations. The team is trying to develop an alternate to alloy 751 (the industry standard for yield strength), which operated at an increased operation temperature for higher efficient engines that require improved material performance and increased oxidation resistance. It is expected that advanced combustion engines (ACE) will require valve materials to withstand 50,000 pounds per square inch (psi) at an operating temperature of 870°C. Therefore, there is a need to develop materials to withstand this environment. The approach used within this project to achieve those results is an oxidation resistant coating applied to lower cost, higher strength alloy materials.

Reviewer 3:
The reviewer asked what oxidation mechanism is being mitigated. If it is oxidation plus fatigue, then please describe why a particular type of coating is needed and why the specific coating was selected. The reviewer asked for a description of the need for a 50-µm thick coating in terms of fatigue and the fact that a diffusion layer is needed for some reason. If this may be proprietary, a few words on how the coatings were deposited 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:
Alloys with significantly increased strength at high temperatures have been achieved. The team did great modeling work to identify coatings to enhance oxidation resistance. To date, high-cycle fatigue (HCF) results are encouraging and there are no coating failures.

Reviewer 2:
A slurry coating and thermal spray coating (MCrAIY) was applied to the 2687 alloy. There was a variation in successful coating depositions. The thermal spray coatings had homogeneity issues in the first batch. As such, the deposition parameters and heat treatment need to be optimized for this approach to be successful. Titanium (Ti) content of the alloy created oxygen (O_2) sensitivity during annealing.

Leveraging the advanced computing capability (included as part of the funding for this project), the project team successfully predicted the microstructure using coupled thermodynamic and kinetic models. These calculated phases are consistent with the phase mapping for slurry coatings. The project team demonstrated significant oxidation resistance using the nonoptimized slurry coating at 900°C. Although the alloy contains Ti for strength, it does create two issues: reduced oxidation resistance and diffusion from the substrate to the coating surface. A concern here is the cost to implement a homogeneity deposition approach for coating the alloy.

Initial HCF tests of coated specimens show no cracks in the coating. Cycles to failure of coated specimens was similar to that of the standard alloy.

The reviewer understands that this project is to develop HT coatings for valve alloys; however, the cost for slurry and spray coatings was never addressed, although it was stated as a clear barrier to HT coatings.

The milestones scheduled for this period include initiating HCF testing of the high strength, coated valve alloy (complete) and writing a paper on the HCF properties of the coated valve alloys (on target).

Reviewer 3:
Slide 8 talks about the bare 31V alloy. Can this material be defined? Is the team trying to match 31V with the 2687 plus a coating?

Referring to Slide 8, if the presence of Ti is an issue, how will this be circumvented?

On Slide 9, there are three data points. The reviewer assumed that two of them in blue are 31V, although this is not stated explicitly. Is it that the base material will control fatigue because the third bullet states that there are no cracks in the coating? Are there any fatigue data for the 2687 alloy without a coating as a baseline?

It would have been helpful to state that a certain mechanism or outcome in the coating layer would be of value (i.e., thickness, interdiffusion layer, etc.), and that this was accomplished. Slide 7 talks about the elemental distribution calculated against what was measured. While these agree, is this the profile that the team wants? Does the team prefer a thicker interdiffusion zone (IDZ) or a thinner IDZ? Is the presence of the sigma phase a benefit or a detriment?

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
A collaboration between the lead National Laboratory (ORNL), academia (Stony Brook University) and an industry partner (Flame Spray, Inc.) was established. Also, the team leveraged advanced computing capabilities as well as coordinated within the PMCP to ensure communication between research institutions.

Reviewer 2:
There is an excellent selection of collaborators. It would be nice to have an OEM, even if in a support or consulting role. It will be interesting to exploit the synchrotron setup in MAT179 to look at the cycling effects on interfacial behavior.

Reviewer 3:
There are two industry partners.

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

Reviewer 1:
Only a very high level plan was presented, making it difficult to assess all aspects of this question. The reviewer would have liked to see at least one slide which provided an overview of the 5-year plan with specific milestones and decision points.

Reviewer 2:
The PI for this project has proposed several areas for future research, with the most important being the optimization of the coating application to ensure homogeneity in the coating deposition. If this cannot be achieved cost effectively, then this process will not be a viable approach to coat valve alloys.

The PI also proposed continuing the cyclic oxidation and HCF testing at higher temperatures. Also, the use of the advanced computational facilities to predict lifetime through couple thermodynamic and kinetic modeling is an effective approach to ensure that these solutions are viable prior to bench scale testing.

If there are cost benefits to using these methods of coating the alloy, this should be included as part of the project. Also, future work proposed by the PI suggested the evaluation of strategies to mitigate the deleterious effect of Ti. The reviewer suggests that the application of these HT coatings to lower costs and lower TI content alloys is developed in parallel to this coating assessment as part of this work. This might be a better approach to addressing the concerns that Ti is presenting.

Reviewer 3:
The plans for future research are well laid out and map the results section. However, there is no mention of what optimized coating fabrication will be used for, and what strategies will be used to mitigate the deleterious effect of Ti, considering Ti is needed for some other reason. The reviewer would like to know if this can be eliminated if Ti is not needed.

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

Reviewer 1:
Enabling increased operating temperatures in combustion engines will enable improved fuel efficiency.

Reviewer 2:
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:
This technology can enable more efficient powertrains in terms of improved fuel economy and reduced emissions.

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

Reviewer 1:
The project appears to be achieving the stated milestones within the allocated budget.

Reviewer 2:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 3:
A good selection of researchers are on this project.

Presentation Number: mat184
Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys
Principal Investigator: Yuki Yamamoto, Michael P. Brady (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 indicated that the project was relevant to current DOE objectives, 0% of reviewers indicated that the project was not relevant, and 0% of reviewers did not indicate an answer. 100% of reviewers indicated that the resources were sufficient, 0% of reviewers indicated that the resources were insufficient, 0% of reviewers indicated that the resources were excessive, and 0% of reviewers did not indicate an answer.

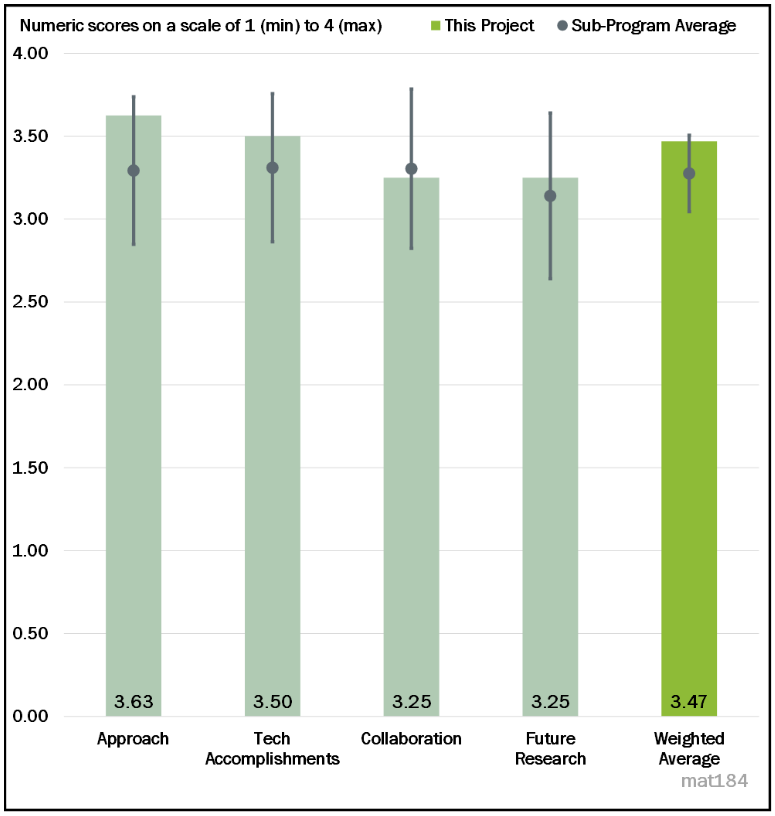

Figure 6-38 - Presentation Number: mat184 Presentation Title: Development of Cast, Higher Temperature Austenitic Alloys Principal Investigator: Yuki Yamamoto, Michael P. Brady (Oak Ridge National Laboratory)

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 objective of this project is to develop cost effective, Fe-based (austenitic) alloys that can be used at temperatures of 900°C-950°C, while providing good oxidation resistance, high strength, and creep resistance. The approach used here is to develop alumina-forming austenitic (AFA) alloys. The performer is taking advantage of integrated computational materials engineering (ICME) approaches, and the project includes validation of newly developed materials at multiple production scales, including collaboration with a commercial partner to produce industry-scale castings. The approach seems sound.

Reviewer 2:

This reviewer referenced Research Thrust Area 2B1—Cost Effective Higher Temperature Engine under the Powertrain Materials Core Program, and commented that the approach used to investigate the impacts of many different materials for powertrain use in the PMCP is an excellent strategic tactic to leverage limited resources and investigate several potential solutions.

The FY 2019 budget was $275,000 and the FY 2020 budget was $275,000. The period of performance for the 3-year (2018-2021) activity is 50% complete and the project aligns with the PMCP timeline.

There are several barriers to overcome and technical targets to hit. Internal combustion engines currently need higher temperature capable materials to permit high efficiency operation; however, the current cost of these materials is high. Traditional development of new materials is costly and time consuming, and it is often difficult to scale new materials to commercial level. Current alloys lose oxidation resistance and strength above 800°C, and Ni-based alloys cost 3-10 times more than Fe-based materials.

So, for this project, the objective was to develop Fe-based alloys for 900°C-950°C applications. By using the aluminum oxide (Al_2O_3) scale formation (AFA alloys), improved oxidation resistance can be achieved. The integration of nanoprecipitation can increase strength and creep resistance. All of these will be demonstrated using an Fe-based alloy with Ni percent weight at or below 25%.

All milestones have either been completed on schedule or early. Upcoming milestones are on target for completion (however, the COVID-19 impact may delay this project slightly because of restricted access to the laboratory).

The approach to accomplish this project is a well thought out stepwise process. The project approach contains four major steps as follows: cast Al-forming austenitic alloys that will provide better protection than the chromia scale; using ICME (CALculation of PHAse Diagrams [CALPHAD] databases) to minimize the alloy selection iteration process; validating material physical properties in the laboratory via experimentation with 1 pound or less of material; and evaluating production feasibility with trial industry scale-up heats using 50 pounds or more of material.

Reviewer 3:
There is a well-rounded approach focused on surmounting the stated technical barriers.

Reviewer 4:
The project approach is well planned. The barriers for developing Fe-based alloys to operate at greater than 900°C have been identified. The approach to address the barriers has been laid out well. However, a task to conduct a techno-economic analysis for the final selected composition is missing, and the reviewer would like to have known if there is a target cost value. If so, it would be helpful to know if some preliminary analyses suggest that it could be met.

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 has made excellent progress. Using modeling, various alloy compositions were identified. The laboratory-scale fabricated alloys were tested for creep and oxidation behaviors. Several compositions showed the target performance. Based on these results, large-scale heats have been conducted and material properties are being characterized. The progress has met the project milestones.

Reviewer 2:
A new alloy design was developed to maximize strengthening carbide ($M_{23}C_6$) formation. To achieve this, five AFA alloys were tested (22-25% Ni) to determine maximum $M_{23}C_6$ formations for strengthening. Although all five are oxide inherent, Al_2O_3 is far more resistant in water (H_2O) exhaust than Cr (III) oxide (Cr_2O_3) resists rapid Feoxide formation and spallation.

This new alloy improved creep performance, exceeding competitive industrial cast austenitic steels. All of this was done with AFA5, with a raw material cost within 5% of the HK30Nb alloy. It was noted that Ni variation has little impact on creep but having less than 20% Ni led to a negative impact on oxidation.

Trial-scale industrial heats of AFA5 (80 pounds of material) is underway, with property screening in progress to determine the tolerance of the alloy to typical microstructure and chemistry variations in the industrial casting process, which will be key.

Reviewer 3:
Five alloys showed excellent oxidation resistance in simulated exhaust gas environments through Al_2O_3 scale formation. Protective Al_2O_3 on AFA5 after a 1,000-hour test improved creep performance in cast austenitic steels.

Reviewer 4:
The project is generally on track and meeting the milestones, with a possible delay in one upcoming go/no-go decision milestone due to a slowdown in experimental work during COVID-19. The down-selected alloy is on track to meet creep and oxidation targets; however the team reports that it may have degraded strength, and this is being investigated.

The milestones appear to be focused primarily on the research process, rather than the performance of the materials developed. For example, one milestone is to “procure an industrial cast heat of down-selected AFA,” and another is to “complete at least 500 one-hour cycles of oxidation testing.” There is not much apparent focus on the technical metrics against which new materials are being measured (strength targets, etc.). This would be useful context for understanding and assessing the technical progress being made and to maintain project momentum.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Partnerships with other National Laboratories and industry are in place. MetalTek International is an industry materials supplier under subcontract to supply the alloys. PNNL is collaborating with ORNL in other PMCP thrust areas. Specifically, collaboration within the PMCP Thrust Areas 4A and 4B were to leverage advanced characterization and computational models. PNNL will help with microstructure characterization (scanning electron microscope [SEM], transmission electron microscopy [TEM], atom probe tomography [APT]) under PMCP Thrust Area 4A, to aid in understanding and optimization during alloy design and scale-up efforts. ORNL Computational Sciences is providing assistance under PMCP Thrust Area 4B to explore novel AFA alloy design with machine learning (ML) (MAT194).

Reviewer 2:
There is excellent collaboration with the PNNL partners for characterization, industry for heats, etc., and the Computational Science Group at ORNL.

Reviewer 3:
This project seems to be fairly well coordinated, with defined roles for each collaborator. The industrial partner, MetalTek International, is currently functioning primarily as a materials vendor. It was not clear how well the parallel ORNL efforts in data analytics and ML were integrated into the material development phase of the project, as this is proposed as future work (it might have been more beneficial earlier on in the process). The analytics work was being carried out under a separate thrust—MAT194— so perhaps results to facilitate such an early integration were not available sooner.

Reviewer 4:
Additional details on contributions from Metal Tek International would help.

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

Reviewer 1:
Overall, the project approach is good. It follows the logical development process from modeling the alloy compositions, to synthesis and characterizations, and eventual scale-up. However, one of the key steps that is missing is some sort of techno-economic analysis for the cost and performance of the new alloys and the

comparison to other state-of-the-art alloys. The reviewer wants to know if the alloys being developed will find acceptance by the engine manufacturers. This risk needs to be addressed sometime in FY 2021.

Reviewer 2:
This project is now focused on an exploration of feasibility and scale-up, now that a promising alloy has been down selected. The proposed future work includes a wide range of activities, including sensitivity analysis, castability studies, mechanical property testing to develop an alloy datasheet for the new material, prototype component production, and integration of ML and data analytics to optimize the alloy design (collaborated supported). These are all valuable things to do, but the project team may need to narrow them down to build a cohesive plan for the remaining 1½ years in the project. The team is still developing milestones and a workplan for the final year of the project (milestones past September 2020 are not yet defined). Over the next few months, the team will need to narrow down to focus on the most valuable efforts, since it seems unlikely that all of the proposed research avenues could be pursued- and brought to a satisfactory conclusion- within the final year of the project.

Reviewer 3:
Future research to complete this project will focus on the industrial casting feasibility evaluation. Also, from the collaboration with Thrust Areas 4A and 4B, the team should gain a better understanding of and guide alloy scale up for advanced characterization and computational models (ML, data analytics). Also, if funds and time permit, the project team will attempt to cast a trial component, which will confirm the castability and homogeneity of the material.

Reviewer 4:
The reviewer wanted to know why ML is needed for novel AFA alloy design and what commercial alloys have resulted from ML. The reviewer was not sure what value data correlation and visualization is bringing to the project. Collaboration with materials and automotive suppliers would greatly benefit this project and steer it toward the realities of commercial casting and component production.

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

Reviewer 1:
The project focuses on lightweighting and material performance improvements under extreme environments and meets the scope of DOE objectives.

Reviewer 2:
This project, focused on developing higher temperature austenitic alloys, supports DOE's goals of increasing the energy efficiency of ICE engines via higher temperature operation.

Reviewer 3:
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 4:
The project supports the DOE objectives for fuel savings. Development of new, high temperature alloys will allow vehicle engines to be operated at higher temperatures and pressures, resulting in increased efficiencies and reduced fuel consumption. In addition, low cost alloys will not impact the overall vehicle costs, as compared to Ni alloys.

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

Reviewer 1:
This project was completed on schedule and the funding appeared to be sufficient since all of the stated objectives were completed.

Reviewer 2:
The resources appear to have been sufficient for this effort.

Reviewer 3:
Adequate resources were available for the project, including computational, material, and commercial thermodynamic software such as JMatPro and Thermo-Calc.

Reviewer 4:
Resources are sufficient, but a better description as to who is doing what within the collaborator base would be helpful.

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

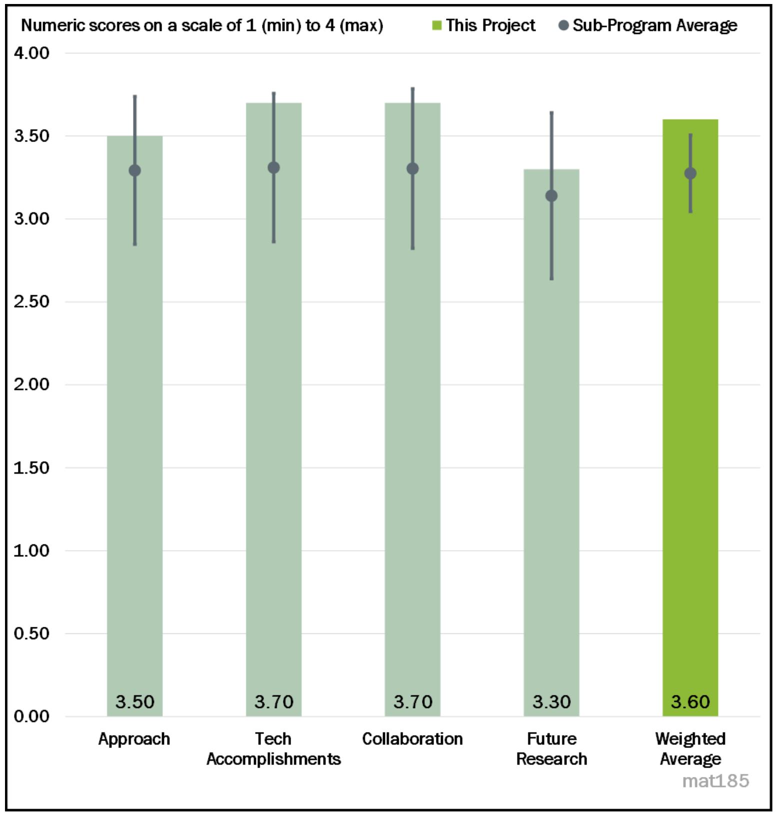

Figure 6-39 - Presentation Number: mat185 Presentation Title: Additively Manufactured Interpenetrating Composites (AMIPC) via Hybrid Manufacturing Principal Investigator: Derek Splitter (Oak Ridge National Laboratory)

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:

This project falls under Subtask 3A2—Hybrid Manufacturing of Additive Manufactured Interpenetrating Phase Composites (AMIPC) of the PMCP in Research Thrust Area Additive Manufacturing of Powertrain Alloys .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.

The budget for FY 2020 is $220,000 and the total budget is $1.1 million, which is $220,000 per year for 5 years. The project timeline for this activity is October 2018 through September 2023, and the project is currently 30% complete. This activity is coupled with Thrust Area 4.

The reason for this project is to find material challenges that can withstand and survive high energy impacts on pistons during knock and stochastic pre-ignition (SPI) conditions. To date, conventional material properties have limited material selection. However, heterogenous material systems are a promising technology that may lead to the development of material properties that can withstand these challenging environments.

The approach developed by the PI to obtain these results is to produce multi-metallic components while enabling opportunities for lightweighting. This approach breaks conventional materials tradeoffs and enables new design and efficiency opportunities. To achieve this material property, a hybrid process was used. AM is combined with melt infiltration (molten Al) with advanced characterization. Computer aided design (CAD) and finite element analysis (FEA) characterizes the behavior in the laboratory. A preform is used to strengthen the AM, and the design approach for the FEM includes AM reinforcement, an interface, and the infiltrated matrix for preforming.

This out-of-the-box approach provides the opportunity to develop the materials needs for high compression engines.

Reviewer 2:
There is very good use of modeling (finite element analysis [FEM]), experiments, and advanced materials characterization, and an excellent validation of modeling approach. Novel material properties were achieved by combining new AM potential with traditional casting. The requirements for binding between the printed and cast materials is still unclear, in addition to if the FEM model is considering potential interface failures or just different material properties.

Reviewer 3:
The project is producing very interesting results. The original selection of the lattice geometry and orientation is not clear based on success in other industries, as pointed out in the "reviewer questions" response. The team is deploying the type of evaluation and analyses capabilities that would be expected of a National Laboratory-led project. The identification of future areas of study based on the results being observed shows a very good level of understanding in how to remain flexible in the overall approach while striving toward the stated goals. More emphasis on the failure modes would be extremely instructive. The excellent characterization of the loaded specimens- such as in Slide 6- is not clarified with respect to initiation mechanisms and propagation, although this would appear to be addressed in detailed fashion through the high quality FE simulations.

Reviewer 4:
Obviously, the approach is successful given the improvements, but without more discussion of the underlying science, it is hard to determine whether or not the results are truly optimum. Because the reviewer missed the window of opportunity to ask questions, there are a lot of unanswered questions about the motivation for the approach which the reviewer would have liked to have heard. The reviewer would like to have known how the team decided on a hybrid approach. The reviewer's understanding was that if the approach is a recipe, the team changed the ingredients and changed the amounts of the ingredients but did not change the steps. Also, the reviewer was curious as to why the third parameter was not varied, and if someone has tried this hybrid approach before but with different ingredients. In addition, the reviewer wondered if the team had a reason to think this would not have worked, what the underlying science is, and why the team would be surprised about non-linearity. Given the non-linearity, the reviewer wanted to know if the team could have better explored the area of rapid change.

Reviewer 5:
The reviewer asked for confirmation of the plan view of the piston in order to understand how much of the piston is being reinforced with the lattice and a description justifying this approach to solve this problem. Because the team is creating an expensive technology, why is such a regular lattice produced by an expensive 3-D printing process needed? The lattice is too coarse at a spacing of 2.5 mm. The temperature changes substantially within a millimeter of distance from the surface.

Why could a 316L fiber mat or foam not be used? There are other materials obtained in this form that are much cheaper and have a much smaller inter-fiber reinforcement. Ceramic fiber mats could also be used.

The reviewer noted that bonding of molten Al with 316L is generally poor so there will essentially be a mechanical bond. Is a coating being used? This will add cost as well. Was any modeling done to show how much the heat transfer would be affected with a 40%-50% stainless steel lattice?

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 is demonstrating extremely good progress in the overall presentation of this novel material system for pistons. The combination of fracture characterization, stress analysis through single-prolonged stress (SPS), and detailed FEA provide a clear picture of the behavior and motivation for future work. The optimization of the lattice geometry and orientation appears to be critical and is rightly pointed out as an area of focus based on the results. The ability to adjust these characteristics is endless based on the capabilities of AM, so the future work component is exciting to consider. The damage tolerance issue has multiple other dimensions to consider, not the least of which is a compatible material system in a stressed composite. The team indicates- at least in a cursory fashion- that this is still part of the evaluation matrix and is a consideration that can heavily leverage finite element work for optimization.

Reviewer 2:
There is an outstanding model correlation with the experiments. It is nice to see that samples have been fabricated and testing has been completed at this stage of the 5-year program. The reviewer would like to know if excellent energy absorption makes this material good for structural components to improve crash worthiness.

Reviewer 3:
Progress is excellent because several milestones were completed ahead of schedule, and an order-of-magnitude improvement was seen in the strain tolerance.

Reviewer 4:
The project results to date have found that there is a nonlinear trade off volume fraction of the reinforcement and the infiltrated matrix. Proposed testing materials include (1) Reinforcement: Ti and stainless steel and (2) Infiltrated matrix: Al or Mg. To date, the AM 316L stainless steel reinforcement and the melt A356 Al infiltrated matrix have been tested. The team is using these behaviors to improve design iterations.

De-localized failure mechanisms are under exploration since delocalized damage greatly increases strain to failure. This knowledge is directly applicable to the survivability of brittle piston failures in the ringland area. The investigating team is coupling results to property relations relevant to pistons (thermal conductivity, specific yield strength) to develop new material systems.

A FEA model is being used to develop new material systems, bridging conventional boundaries. Tensile load is only being carried by the AM 316L stainless steel reinforcement. A key factor is that the design of the reinforcement must not surpass the ultimate tensile strength (UTS) to permit transition to high damage tolerance. Lattice geometry optimization is a logical next step in this design process. This approach is being considered for multi-material bonding applications.

Shock loading and fatigue are guiding the future project path. These factors can impact the entire engine design. It is critical to minimize the engine damage caused by shock. It appears that this bi-metallic approach of combining AM and melt infiltration can achieve very high damage tolerances.

Both FY 2020 milestones have been completed ahead of schedule.

Reviewer 5:
Excellent progress has been made as a standalone project in terms of understanding the material. However, the data should be presented in relevance to the requirements of a piston. The benefit in piston applications is strictly related to yield strength, because once there is any deformation, the rings will start to lock up. From this standpoint, only the 50% reinforced material looks better. However, 50% is a huge amount of reinforcement. By the time the material reached the crack bridging phase, the material is of no value to a piston. The reviewer would like to know if the data in Slide 6 are at room temperature, and if so, why it was

not at the elevated temperature of 275°C. In addition, the reviewer wants to know why 356 was selected because it is not a piston alloy and encourages the team to use the hypereutectic silicon alloy 390.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There are no apparent shortcomings here. The role of Bechtel is not entirely clear, but progress is being shown and the quality of results indicate that the team is functioning at an appropriate level.

Reviewer 2:
The team appears to have good collaboration with academia and industry. The results are being published and are drawing interest in additional applications outside of vehicle technologies.

Reviewer 3:
The reviewer found the collaboration to be outstanding for multiple reasons: There is an impressive, collaborative publication output,

the company sought the team for work outside the vehicle market, and work is being done with both the MDF and Spallation Neutron Source (SNS).

Reviewer 4:
Partnerships with academia and industry are in place. Rice University (vacuum casting technique development) and Bechtel (industry partner providing project direction advising and the potential for expanded utility) are active participants in this project. The PCMP Task 4 work in crystal plasticity modeling of an Al matrix for optimization opportunities in tension loading is being coordinated with this project. Also, through the PCMP, other National Laboratories are being informed about this activity.

Reviewer 5:
This is an excellent team of well-qualified individuals. Having an OEM support or consult would be of benefit.

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

Reviewer 1:
Future work focuses on shock loading and scale-up to a component level. There is interest in using this research in other applications outside of vehicle technologies after releasing some of the findings.

Reviewer 2:
Proposed future research that was presented at a very high level is good. It would be very good to see cyclic load testing and impact testing to understand if there are any detrimental interface effects that large plasticity testing does not identify. No detailed plan with future milestones and decision points is provided, and there is no linkage to a project budget.

Reviewer 3:
This project is hard to judge, as it is only 30% complete. Of course, scale-up is a good idea, but the reviewer would like to have seen discussion of how that might be done to take into account the nonlinear response, in addition to how to optimize the amount by which is should initially be scaled up. Knowing what the team gets with scale-up and why it would be so different from the current scale would be good.

Reviewer 4:
The indication that the team will be looking at optimization of the lattice geometry is one of the key highlights of the proposed future work. Additionally, the suggestion that shock loading and fatigue are next steps will be

critical to the overall study. The fracture patterns in the composites (particularly with respect to interfaces between A356 and 316L) are going to provide an immeasurably level of importance of information regarding the damage accumulation and the ultimate failure mechanisms in this novel system. The shock loading is not as interesting as the fatigue component in the reviewer's opinion. The fatigue cycles in a piston groove build up to extremely high numbers, and the initiation of a crack early in the projected life may prove to be a severe limitation. The team points to "scale up to component level," but no specific mention is made of component testing. The reviewer would like to know if this is planned.

Reviewer 5:
The reviewer asked for an explanation of why a strut and node geometry will provide any difference in the outcome of the material properties with reference to a piston application. What did the project team learn that is making the team choose the three new designs? The key consideration is where the product becomes non-usable; it is not at 20% strain for a product that has to operate at micron tolerances. Are the fatigue properties of the composite system in FEM analysis to be done at the resolution of the finite elements being in the matrix and reinforcement with some criteria for the interface, or will the material be treated as homogeneous?. Please make sure to include the Al piston alloy 390 in baseline calculations.

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

Reviewer 1:
The role of AM in optimizing component performance in automotive applications is still in its infancy. The team is taking a proven approach and applying it to an automotive problem that potentially enhances resistance to failure under extreme conditions, providing an opportunity for extending the efficiency by facilitating operation at more efficient, but demanding, levels.

Reviewer 2:
Bi-metallics is an interesting area for significant exploration for novel material properties. Significant research is needed, for projects, budget, etc.

Reviewer 3:
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 4:
Improving the performance of internal combustion engines leads to a reduction in energy needed and an improvement in emissions.

Reviewer 5:
Enhancing the ability to lightweight supports DOE's energy efficiency mission, whereas increasing safety does not do this so much, aside from indirectly increasing competitiveness.

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

Reviewer 1:
The project is making good progress with the stated budget.

Reviewer 2:
Even at a DOE laboratory, $1.1 million should enable a thorough exploration of this area. Given that it is ahead of schedule and already getting great results, the scope might possibly be realistically expanded to include a study of more variables.

Reviewer 3:
This project is on schedule and the funding appears to be sufficient since all of the stated milestones have been completed on time (to date).

Reviewer 4:
There is a good selection of researchers.

Reviewer 5:
Detailed tasks and milestones within the budget were not provided. The reviewer cannot adequately comment on this question. This information seems to be generally lacking from several of the DOE laboratory presentations.

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

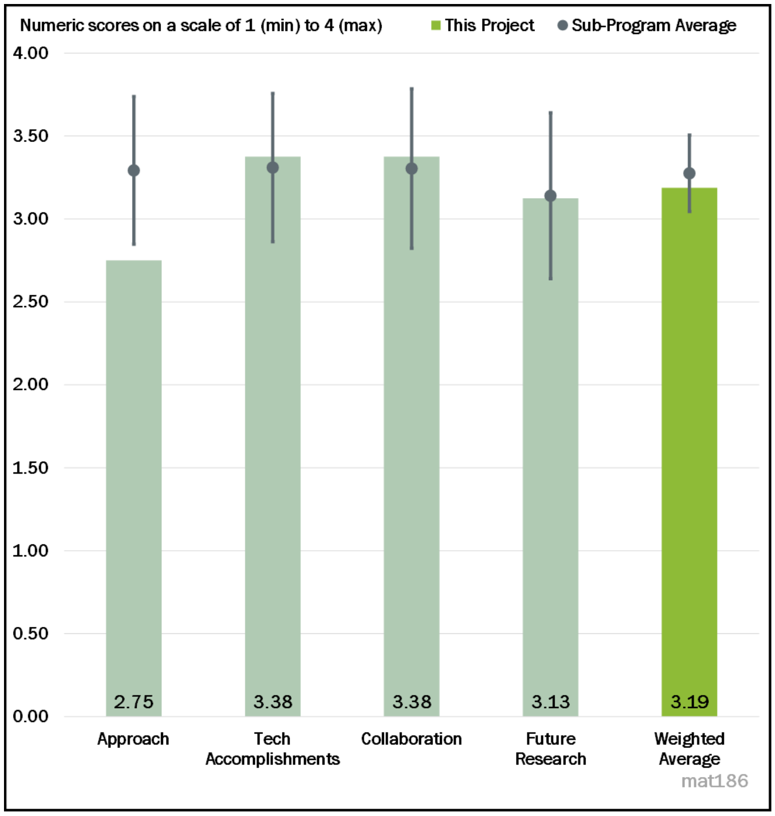

Figure 6-40 - Presentation Number: mat186 Presentation Title: Modeling of Light-Duty Engines Principal Investigator: Charles Finney (Oak Ridge National Laboratory)

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:

There is currently a wide range of research works going on related to corrosion and oxidation of automotive engines at ORNL. Using computational and experimental tools, this project is addressing one of the significant components of lightweight engines with high power density materials. This project is divided in two parts. Of the major activities proposed, the first one is to predict and develop new materials for lightweight engines which can operate at extreme conditions such as high temperatures and pressures. The second is to increase the efficiency by reducing emissions and predicting material properties. The third is developing and estimating the affordability of advanced engine materials and components. The fourth is accelerating the time for advanced materials. Lastly, investigators will use the experimental tools for scaling the new alloys for commercial use.

Reviewer 2:

The proposed modeling approach including FEA and computational fluid dynamics (CFD) is good, but there is no clear advantage or difference from the engineering modeling approach practiced in the automotive industry. Due to the lack of the engine data and models from automotive OEMs to be used for DOE-sponsored research, this project has value in providing data and models to support engine materials and process development. However, there seems to be no scientific and technological novelty in this project.

Reviewer 3:

The project appears to duplicate thermal engine and stress modeling work, which is already being done by the OEMs using proprietary methods and targets. Therefore, it is not clear why this simulation effort is needed to set future materials targets. The benefit of this project would be to expose the conclusions of future material needs to the public; however, it is unclear who would take advantage of these conclusions that has not already been given access to them by an OEM seeking superior high temperature material properties. The project also appears to be at a disadvantage because it does not have direct access to the engine CAD, relying instead on a labor-intensive process of building a solid model from a high definition 3-D scan.

Reviewer 4:
The team plans to use mechanical and CDF simulations of engine behavior to establish material property requirements for future lightweight engines. However, the team did not discuss any efforts to determine what the most critical material properties are, nor did the team provide a list of what material properties plan to be investigated. The focus seems to be more on the approach (mesh generation, running the models, etc.) rather than on the objective of determining the material property 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:
The reviewer rates this as a very good proposal and investigators made excellent progress. An excellent strength of this project is the systematic approach to find a material or materials to increase the power density.

Reviewer 2:
The project has generated significant modeling results which can be used to guide materials development and process innovations for high performance engine development.

Reviewer 3:
The project is going about achieving the stated milestones with the best possible method under the apparent intellectual property (IP) restrictions.

Reviewer 4:
The team has made good progress so far.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation, it is very clear that the coordination between the investigators is good, and the major research of this project is highly interdisciplinary in character.

Reviewer 2:
There are excellent collaborations within the project team.

Reviewer 3:
Collaboration within ORNL and with Convergent Science, Inc. seems to be fruitful. Two OEMs are said to be involved, but do not appear to be participating in the project at fullest potential. It seems that an enabler for this project would be to partner more extensively with a LD engine OEM to ensure grounding in geometry and method of evaluation.

Reviewer 4:
The collaboration seemed fine.

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

Reviewer 1:
Future research seemed reasonable.

Reviewer 2:
The reviewer suggests exploring new simulation methods and approaches, such as ICME, based on location-specific properties.

Reviewer 3:
Investigators made some progress on the project using a systematic approach and they predicted two different materials for the heavy-duty (HD) engine. The reviewer's suggestion is that investigators should check the surface and chemical properties of the materials. The concern is that there is no detail about the computational materials procedure and results.

Reviewer 4:
The project plans to use a finite element simulation process developed for HD cast Fe cylinder heads and applying it to a LD cylinder head currently made of Al. The failure criteria used for a brittle cast Fe should probably not be the same criteria used for ductile Al; however, an appropriate Al failure criterion likely exists.

Setting targets needs to be done with more OEM collaboration than what is stated in this project. The goal of defining future material needs is worthwhile, but without engagement from teams that work on this problem on a routine basis, the effort may yield little new value.

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

Reviewer 1:
Development of high temperature cylinder head alloys enables higher power density engines and reduced fuel consumption.

Reviewer 2:
The project is highly relevant.

Reviewer 3:
Yes, the project supports overall DOE objectives. High power density material is the key component of the engine performance. New materials are needed for next generation, fuel efficient engine. In this project proposal, investigators explain the systematic approach to find out new materials with high power density. Combining the experimental and computational approach can have a broad impact on the development of a lightweight engine.

Reviewer 4:
This is useful work, but it lacks novelty in the simulation methods.

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

Reviewer 1:
There is sufficient funding for modeling work.

Reviewer 2:
Resources appear to be sufficient to complete the stated milestones; however, the milestones only describe activities which will be performed- not deliverables such as new insights which will be gained or key questions which will be answered.

Reviewer 3:
The resources seem fine.

Reviewer 4:

The reviewer’s major concern is related the subtask 4B4. Investigators finished only 22% of the project work, and the remaining 78% of the project’s future work road map is not convincing to the reviewer.

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

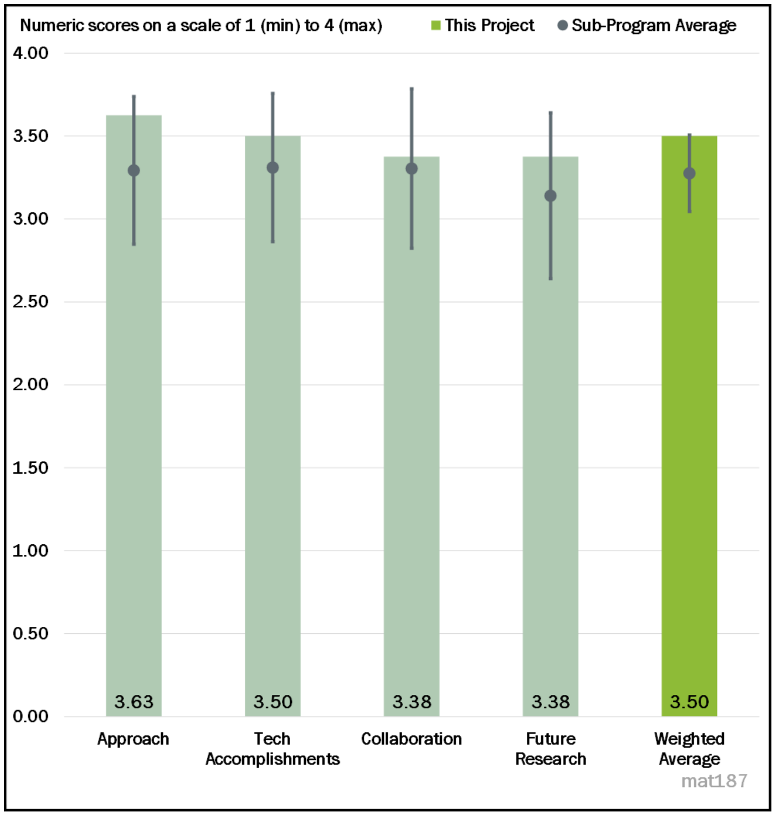

Figure 6-41 - Presentation Number: mat187 Presentation Title: Fundamental Studies of Complex Precipitation Pathways in Lightweight Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

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:
The reviewer referenced prior comments.

Reviewer 2:
The project is based on fundamental density functional theory (DFT) calculations to model the interfacial energy and precipitation in Al alloys. The modeling research is also supported by a high quality characterization study.

Reviewer 3:
This project is leveraging the advanced experimental and computational tools available at ORNL and other partner facilities to explore complex precipitation pathways in lightweight alloys.

Reviewer 4:
The approach seems reasonable. Manufacturability should be considered as soon as possible to help identify the best alloy compositions.

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:
Progress is excellent. The reviewer suggests investigators to check the surface and chemical properties of the alloys. If investigators explain the thermodynamics using potential energy surface, then it will be great. The reviewer also requests that the investigators make open source computational tools to further develop the lightweight engine.

Reviewer 2:
The project has achieved the interfacial energy calculations of precipitation, including anisotropy and solute segregation effects. The concept of co-precipitation of L12 and aluminum-copper (Al_2Cu) needs to be reconsidered. CALPHAD analysis suggests that L12 phase forms during solidification before the formation of alpha-Al. So, most likely, L12 promotes grain refinement and perhaps heterogenous nucleation of Al_2Cu during aging.

Reviewer 3:
The team has made good progress and mentioned seeing a given defect in the experiment and then explaining that the researchers had to try out several configurations before the DFT predicted that it was an energy favorable state. The reviewer would like to know if the team has plans to use automated approaches to try out various defect configurations with the DFT to discover low energy defects rather than relying on the experimental data.

Reviewer 4:
Several publications were submitted to share the research results.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
From the presentation, it is very clear that the coordination between the investigators is good, and the major research of this project is of a highly interdisciplinary character.

Reviewer 2:
Collaboration within the project team is evident from the results.

Reviewer 3:
Collaboration and coordination are shown with several other academic institutions and National Laboratories.

Reviewer 4:
Collaboration is fine.

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

Reviewer 1:
The proposed path will dig into fundamentals and attempt to populate a dataset to train ML.

Reviewer 2:
Proposed future research is fine.

Reviewer 3:
The future research plan is generally sound. It is suggested to include precipitation kinetic modeling using the Kampmann-Wagner (KWN) or other models.

Reviewer 4:
The reviewer’s concern is related to the first principle calculations. Investigators used the high throughput DFT techniques, but there are still no details on how the team predicted vacancy defects in the alloys. If the techniques are different than the cluster expansion model, then the investigators should explain the differences and compare the results with the cluster expansion model.

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

Reviewer 1:
Understanding precipitation hardening and harnessing its strengthening effects is critically important to the development of lightweight alloys for vehicle lightweighting.

Reviewer 2:
Understanding mechanisms of complex precipitation pathways in lightweight alloys may enable higher temperature alloy development.

Reviewer 3:
The reviewer referenced prior comments.

Reviewer 4:
The relevance is good, as long as overall DOE objectives can be supported.

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

Reviewer 1:
So far, resources seem sufficient in supporting the team.

Reviewer 2:
Resources appear to be sufficient.

Reviewer 3:
Resources were fine.

Reviewer 4:
Although investigators made major progress for the development of new materials, there are some concerns about the project. One of the major concerns is related the subtask 1A1. Investigators finished only 30% of the project work, and, for the reviewer, the remaining 70% of the project’s future work road map is not convincing.

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 two reviewers evaluated this project.

Project Relevance and Resources

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

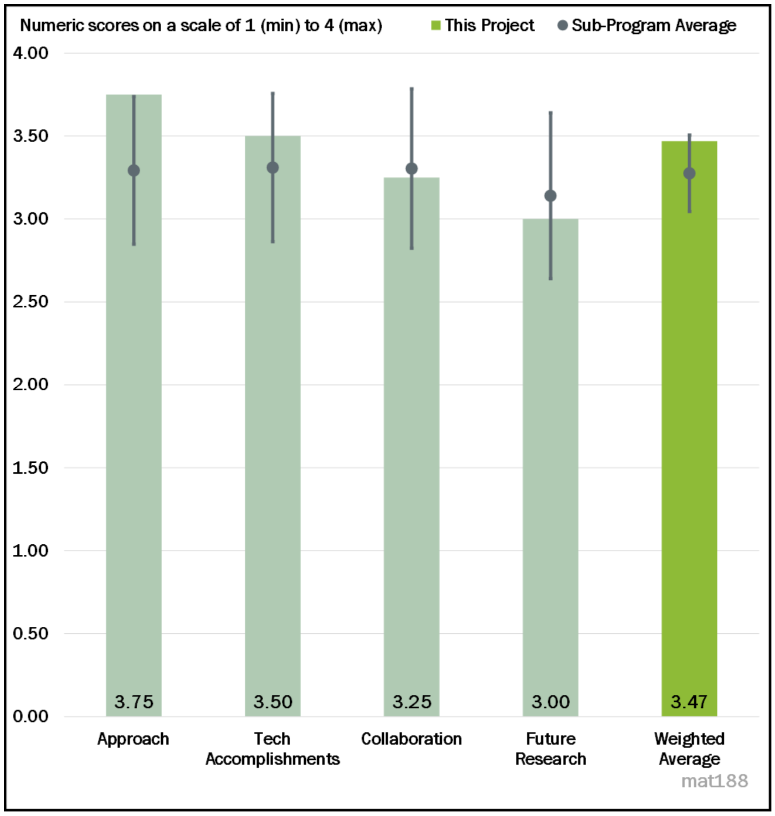

Figure 6-42 - Presentation Number: mat188 Presentation Title: Properties of Cast Aluminum-Copper-Manganese-Zirconium Alloys Principal Investigator: Amit Shyam (Oak Ridge National Laboratory)

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 approach seems solid and well-planned.

Reviewer 2:

Good progress has been made in studying the role of increased copper content on elevated temperature properties. The reviewer agrees that improved properties (yield, ultimate, elongation, and fatigue) at elevated temperatures are very important, but would like to see property targets at a given temperature. This would better allow the team to focus on specific goals.

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 progress seemed reasonable.

Reviewer 2:

Good progress is being made on studying increasing copper levels and correlation to ICME models. Again, a set of targets has not been developed.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The project seems to be broken down into multiple phases with assigned roles for each.

Reviewer 2:
Not a lot of information was provided about how the group interacts and coordinates. This might be something to discuss more in the future.

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

Reviewer 1:
The plans seemed reasonable.

Reviewer 2:
The proposed future research statements on Slide 20 are a bit to general. The reviewer would rather see a more task-oriented list. For example, exploring new alloy systems as future research is very difficult to judge. The reviewer would like to know if this is referring to one new system or ten new systems.

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

Reviewer 1:
This effort addresses the need for improved materials for better internal combustion engine (ICE) performance.

Reviewer 2:
The project does support the DOE objectives.

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

Reviewer 1:
Team resources appear to be sufficient.

Reviewer 2:
The reviewer had no comments.

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 three reviewers evaluated this project.

Project Relevance and Resources

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

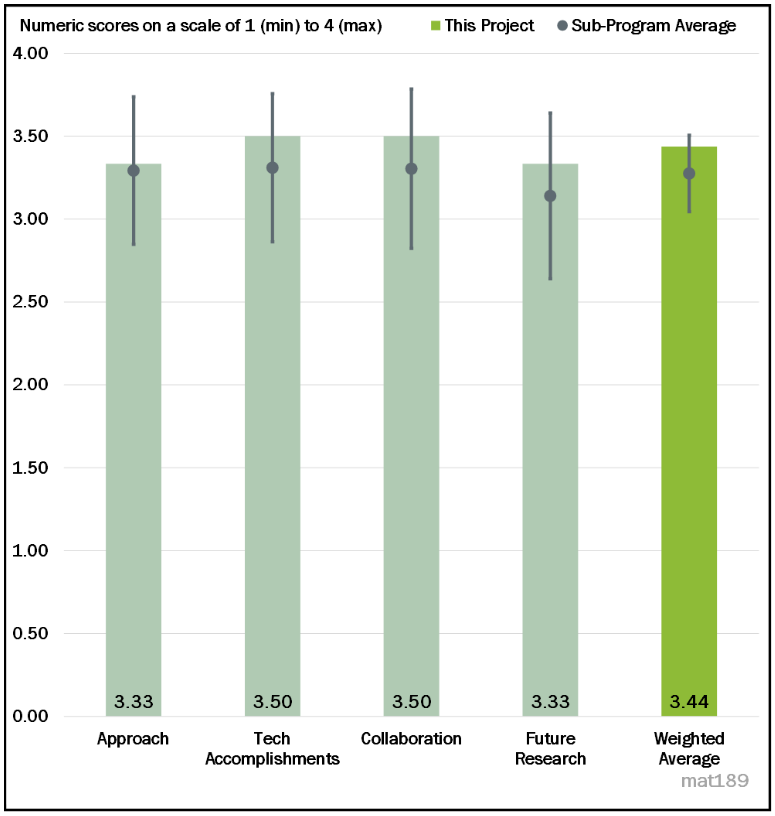

Figure 6-43 - Presentation Number: mat189 Presentation Title: Fundamental Development of Aluminum Alloys for Additive Manufacturing Principal Investigator: Alex Plotkowski (Oak Ridge National Laboratory)

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 is characterized by a highly structured approach, especially the combination of ICME-based alloy design and experimental work that is executed in a model way. Furthermore, all aspects are put into a correct technical and industrial background which proves that this work is rather valuable.

Reviewer 2:

Specific, targeted search regions to minimize hot tearing were identified for exploration.

Reviewer 3:

The reviewer was a bit unclear on the property targets. The reviewer agreed that increased properties are needed at temperatures between 250°C400°C, and that AM can be used to print complex geometries (not possible in castings), but did not see what the targets (yield, ultimate, elongation) are, and at what temperatures.

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:

So far, accomplishments have been made, especially with regard to success in alloy development, and are on track with the research plan.

Reviewer 2:
The team successfully printed and characterized three new alloys with improved hot tear resistance. The performance of these alloys exceeds the aluminum-silicon-magnesium (Al10SiMg) alloy (except elongation) above 250°C.

Reviewer 3:
The tensile properties of the developed alloys show improved strength retention over commercial alloys at elevated temperatures.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There seems to be good collaboration within the project team and with external collaborators.

Reviewer 2:
Coordination of activities across several university partners is explained well.

Reviewer 3:
There is a large team that seems to be reaching the goals. The reviewer suggests defining a set of target properties at various temperatures, so the team knows when the final goal has been reached.

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

Reviewer 1:
The team is continuing to develop and print new alloys in 2020, followed by printing prototype parts in 2021, and testing is reasonable.

Reviewer 2:
The focus of the current study is breadth, simple geometry, and characterization. Future work will narrow breadth and scale-up to more product-like geometries with longer term testing (fatigue, creep).

Reviewer 3:
The proposed future research covers the essential blank spots in the current work. A cross-checking of the hot tearing model and its applicability to the chosen processing route is recommended. A point that has not been considered so far is an analysis of the fatigue properties of the newly developed alloys.

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

Reviewer 1:
HT Al alloy development with AM capabilities provides opportunities for lightweighting of powertrains as well as increased power density.

Reviewer 2:
Performance enhancement of power train materials for a higher fuel economy of ICE vehicles meets DOE´s targets.

Reviewer 3:
This project does support improved engine efficiency based upon improved elevated temperature properties.

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

Reviewer 1:
The resources seem to be on track with the future planned work.

Reviewer 2:
The team is working together to make progress.

Reviewer 3:
Funding appears to be sufficient.

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

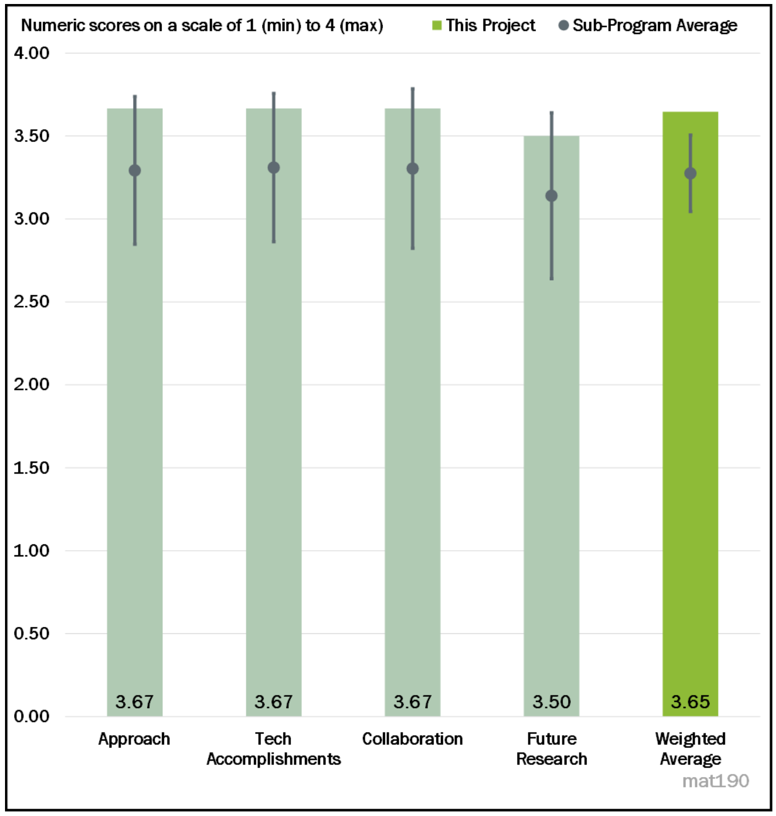

Figure 6-44 - Presentation Number: mat190 Presentation Title: Oxidation Resistant Valve Alloys Principal Investigator: G Muralidharan (Oak Ridge National Laboratory)

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 approach appears feasible and well designed to meet the technical barriers of providing cost effective, higher performance exhaust valve materials to enable higher power density, LD engines. The dual path approach focusing on improving HT strength and oxidation and corrosion resistance by focusing on commercializing lower cost, ORNL-developed chromia forming alloys for use below 900°C, and developing new, higher strength, lower cost alumina forming alloys for use above 900°C provides better odds of developing at least one alloy that can meet the needs of high power density engines without increasing the cost.

Reviewer 2:

The project team has presented very remarkable progress on the development of HT strength and oxidation resistant alloys. The approach taken is scientifically and technically sound.

Reviewer 3:

The work appears to be well planned. Good comparison properties are available for existing commercial alloys and good target properties are in place. The target application is well defined, with a temperature range of 900°C-950°C.

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 so far appears to be in line with the project plan.

Reviewer 2:
Technical accomplishments are well in line to support project goals, with the ORNL-developed chromia forming alloy 161 (M2045) demonstrating improved performance and a lower cost than commercially available chromia forming alloys. The alumina forming alloy 5B achieved a go/no-go target of 241 megapascals (MPa) at 950^{o}C, while demonstrating good oxidation resistance at 950^{o}C, although long term stability of oxidation behavior of new alumina forming alloys remains to be demonstrated.

Reviewer 3:
Good progress is being made on the new alloy and characterization. There are good target properties in place. Some cost factors are listed, but the reviewer cannot tell how they were developed. The reviewer wondered if they were provided by the OEM partner.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
The reviewer is satisfied with the collaboration amongst the project team that was presented by the project leaders.

Reviewer 2:
The close collaboration among the project partners has been well coordinated to achieve outstanding results to date. Close collaboration with industry partners should help to ensure commercialization of the new alloys.

Reviewer 3:
The project is broken into tasks that are assigned to the different laboratories and is now moving to work with industrial partners.

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

Reviewer 1:
It seems logical to continue to characterize the different development alloys and then follow up with larger casts to produce full scale parts.

Reviewer 2:
The proposed research seems fine. However, in light with the proposed application context as valve alloys, experiments should be conducted to evaluate the oxidation and frictional behavior of the alloys at elevated temperatures.

Reviewer 3:
The project has effectively planned future work to build on successes to date to continue evaluating and improving alloys already developed as part of the project, and to move development toward commercialization scale up. Challenges of scaling up the vacuum induction molding (VIM) process may create a significant risk.

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

Reviewer 1:
This project is in line with DOE`s targets to enhance the efficiency of ICE vehicles.

Reviewer 2:
The project supports the DOE objectives of increasing engine power densities and higher efficiency through the development of higher temperature capability exhaust valve materials and manufacturing processes.

Reviewer 3:
The project supports the DOE goal of improved engine performance through material property improvements and cost reductions.

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

Reviewer 1:
The team is making good progress and installing new equipment to speed up the effort.

Reviewer 2:
No shortage in resources seems to be apparent.

Reviewer 3:
Resources seem sufficient for the work planned for the rest of the project.

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

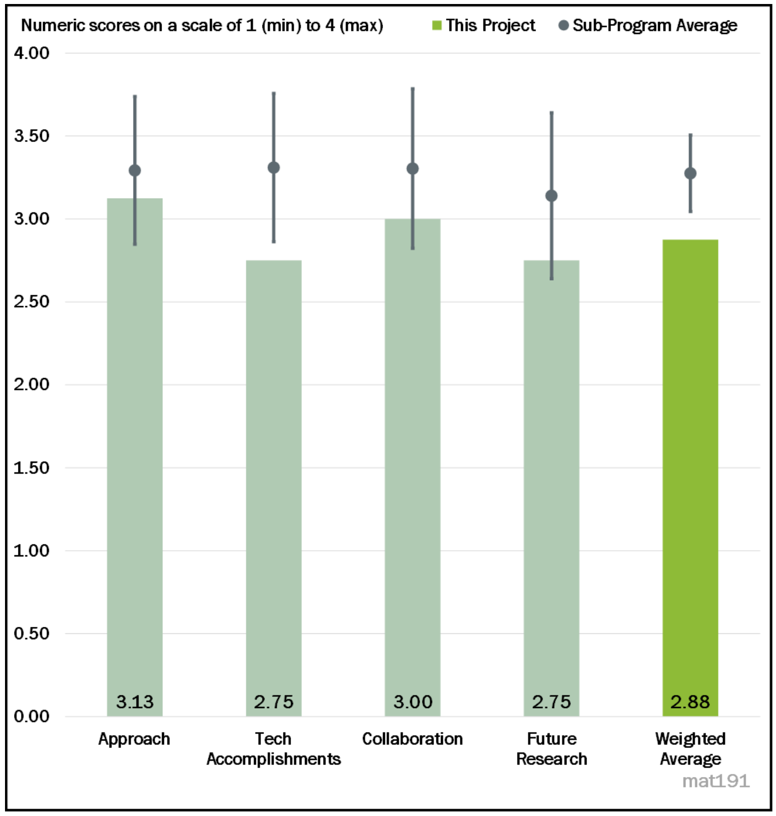

Figure 6-45 - Presentation Number: mat191 Presentation Title: Overview of Advanced Characterization within the Powertrain Materials Core Program Principal Investigator: Tom Watkins (Oak Ridge National Laboratory)

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:

This is an amazing compilation of the phenomenal experimental and computational capabilities at three DOE labs for advanced characterization with powertrain materials. It appears that the technical barriers, while not specifically addressed (e.g., increasing engine power densities and higher efficiencies) are more likely to be resolved with future novel solutions with all of this capability.

Reviewer 2:

This project falls under Research Thrust Area 4A – Advanced Characterization within the Powertrain Materials Core Program under the Powertrain Materials Core Program (PMCP). 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.

The budget for FY 2020 is $1.025 million and for FY 2019 it was $1.05 million. The timeline for this activity is October 2018 through September 2023, and the project is currently 30% complete. This activity is coupled with Thrust Area 4B – Advanced Computation within the Powertrain Materials Core Program. ORNL is the lead DOE laboratory for this effort. PNNL and ANL are the other participating DOE labs.

The challenge that this research is addressing is to develop improved powertrain materials with the characteristics needed for increased pressure and increased temperature performance. These materials are needed in new engines that have increased power densities and higher efficiencies. To accomplish this, a need exists to reduce variables to test and reduce development time to develop low cost, high strength materials economically. The development focus for activities under this project falls under is under three thrusts: (1) Cost Effective, Lightweight, HT Engine Alloys; (2) Cost Effective, Higher Temperature Engine Alloys; and (3) AM of Powertrain Alloys. The laboratory team will use a matrix of experts with unique tools, collaboration, and coordination. Projects are selected to understand the fundamentals of these alloys which is needed to optimize materials to maintain performance in harsh environments. Tools at their disposal include ANL's Advanced Photon Source (APS), PNNL's APT, and ORNL's SNS, and allow the project participants to see the alloy trace precipitate. The team can quantify shapes, spacing, and learn how the theta prime and thetas evolve, understanding the transition with respect to time and temperature. Theta prime precipitate provides strength, and an understanding of the transition to the theta phase provides insight into the material performance.

Reviewer 3:
The approach taken seems to be satisfactory.

Reviewer 4:
Although Task 4A: Advanced Characterization includes highly regarded researchers from three National Laboratories—ORNL, PNNL, and ANL—the approach description lacks any substantive descriptions of how the work accomplishes the overall objectives of the PMCP. The ICME component went largely unexplained, and there was little discussion on how the integration of ICME drives the experimental work.

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:
Technical accomplishments are mostly in the applications of the various experimental methodologies to understand metallurgical features (e.g., precipitates) for powertrain materials. It is not clear if any progress has been made toward the development of new materials or the acceleration of alloy development.

Reviewer 2:
Within the project framework, this subproject primarily offers advanced and tailored characterization techniques as a "service" to most other subprojects. It is clear that this entails pushing the boundaries of conventional characterization techniques, which has partly been completed successfully to date.

Reviewer 3:
Since theta prime carries load, the efficient load transfer is identified by using the SNS. Microscopy confirmed that the phase diagrams were predicted by ICME. ICME is a cost-effective approach to the development of new materials for these specialty applications, and significantly reduces development time and cost by identifying materials capable of providing the characteristics needed for specific applications. PNNL's ATS at the Environmental Molecular Science Laboratory (EMSL) user center can investigate HT Ni-based alloys to understand gamma prime, which provides insights into the material strength. ANL's APS – which allows in-situ heating to grow particles in ORNL's Ni valve alloy- was used to understand gamma prime to understand alloy strength. Other project activities include multiphase identification within a creep-ruptured cast alumina forming austenitic alloy conducted by PNNL and ORNL. These results are integrated into the ICME (funded separately through Thrust 5). This characterization of data into ICME, and integrated with ML, is challenging since there is a requirement to keep data formatting and structure consistent to allow for the integration of the data. All FY 2020 milestones have been completed and future milestones are on-track to be completed on time.

Reviewer 4:
A few research examples were given, but the work lacked any grounding within the larger framework of the core program.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
Collaboration across the three research laboratories is excellent. An industry partner is also participating (Protochips, Inc. located in Raleigh, North Carolina).

Reviewer 2:
The project is particularly designed as to bring together scientific experts from various institutions. This does appear to work quite well.

Reviewer 3:
There is excellent collaboration across the three National Laboratories. The reviewer would like to know what was involved with the ICME that was validated with ORNL's STEM. Was it Calphad only?

Reviewer 4:
Each National Laboratory partner appears autonomous and largely unconnected to the other partners. There is very little collaboration or research integration between the partners. Each partner contributes individually and the need for a team or center-type grant appears unnecessary to accomplish the research goals of the core program.

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

Reviewer 1:
An additional emphasis could be placed on how to link experimental characterization techniques to novel approaches in computational materials science.

Reviewer 2:
Targets for the future research are prioritization of advanced characterization requests and developing an integration strategy of the advanced analytical data into the ICME. The integration of data is critical to increase the data library accessible through the ICME. Three separate activities are proposed, each at being led by one of the National laboratories. ORNL will perform in-situ, HT STEM to correlate thin-foil precipitate evolution to bulk material precipitate evolution, and thereby significantly accelerate alloy development and discovery and structures correlated with thin-foil precipitate evolution to bulk material precipitate evolution. This will significantly accelerate alloy development and discovery. ANL will use the Synchrotron for in-situ loading and tomography studies of valve alloys at temperature with a new flexible, in-situ heating and loading system being developed (through Thrust 5 of the PMCP). ANL will also use the Synchrotron to study- through diffraction- the thermal stability of a new, lightweight alloy to help validate the model. PNNL will characterize the microstructure and fine precipitates in developmental piston alloys with advanced STEM.

Reviewer 3:
Seeking Educational Equity and Diversity (SEED) projects were largely proposed, with little discussion of sensibility, risk, and discussion of barriers.

Reviewer 4:
Several times during the presentation, the reviewer heard that there is interest in supporting industry, yet there was no clear path to doing so. The reviewer is not sure where the ultimate value is coming from, from all of this spectacular capability, and would like to know if the focus is mostly on basic research and publications for the benefit of the National Laboratories. If so, this is great, but there are no obvious connections with industry, and this limits the project to more of an academic exercise, almost as if DOE labs have many solutions with no industrial problems driving the need for the solutions. The reviewer would also like to know why no comparative study of neutrons versus synchrotron X-rays for load transform from the Al matrix to theta-prime

precipitates has been conducted, and which is better for this. Such studies would be invaluable for industrial applications. It is unclear where this project is headed, even though there is a slide with proposed future research.

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

Reviewer 1:
Yes, applications of sophisticated materials characterization and measurement technologies will drive a deeper, fundamental understanding of powertrain materials and add more data for DOE databases.

Reviewer 2:
The project provides fundamental support to a large number of other projects that directly contribute toward DOE´s objectives.

Reviewer 3:
Yes, the project is supportive of DOE objectives in that it provides characterization and a detailed atomic scale analysis of materials and alloys systems that are deemed important to DOE, largely in the area of lightweighting.

Reviewer 4:
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.

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.

Reviewer 2:
There is no indication as to a shortage in resources that have been given.

Reviewer 3:
The resources appear to be sufficient to support the milestones in a timely fashion. No resource shortfalls were noted.

Reviewer 4:
This project is on schedule and the funding appears to be sufficient since all of the stated milestones have been completed on time (to date).

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

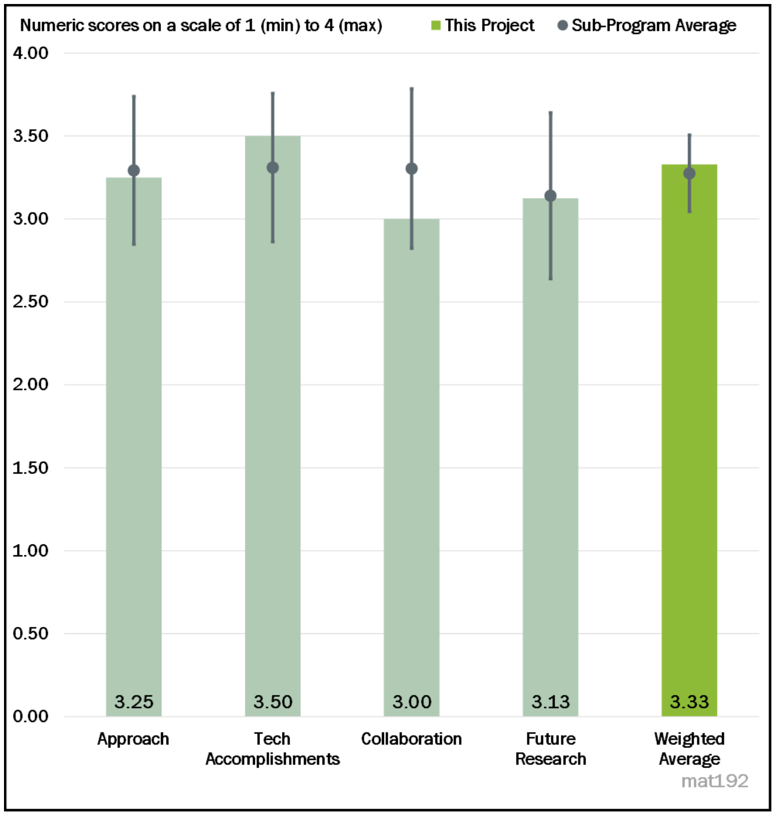

Figure 6-46 - Presentation Number: mat192 Presentation Title: Fundamentals of Austenitic Alloys via Additive Manufacturing Principal Investigator: Sebastien Dryepondt (Oak Ridge National Laboratory)

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:

A very clear approach to the development of austenitic alloys fabricated by AM was provided. This approach included a close integration between ICME techniques coupled with high throughput and advanced characterization. The project was very well laid out and progress made to date has been positive.

Reviewer 2:

The approach taken complies with the project plan and shows sufficient aspects of novelty (for example, the high throughput screening). The results described are well characterized.

Reviewer 3:

Some, but not all, of the technical barriers have been addressed (for example, higher power density, higher efficiency engines, costs of engine materials, development time, scaling to commercialization).

Reviewer 4:

The approach described in the presentation is for the initial experimentation and does not directly address most of the DOE technical barriers described on the overview slides (new alloys for higher power density, higher efficiency engines, cost of advanced engine materials, development time and cost of new materials, scaling new materials technologies to commercialization). The approach addresses the first steps of experimentation to collect data on mechanical properties of alloys, which could address the barrier of no HT data and fast screening of austenitic alloys (as well as leveraging microstructure data from another project) and the development of models using FEA and thermodynamic analysis, but not all the barriers to AM of austenitic alloys (cost and scaling barriers for AM and development time). The approach presented was for experimentation and not for the total project, which will address all barriers. The experimental approach is well designed and feasible since it is a standard approach, but differs only in that it addresses specifics of the AM technology being developed.

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 AM-route demonstrated shows remarkable properties for commercial alloys, which represents a major achievement.

Reviewer 2:
The barriers were clearly defined, and the project has made significant progress, while only midway through the timeline on the objectives and goals. Several "firsts" and notable technical accomplishments were described, indicating good technical progress.

Reviewer 3:
There were good technical accomplishments made using the laser powder bed fusion (LPBF) technique, which produced results for a stainless-steel alloy having very few defects and grains slightly elongated along the build direction. However, the strength at the higher temperatures was lower than expected, possibly due to the stability of the cellular structure. This result is still important for modifying the technique to get a better consistency in the alloy, which should improve the mechanical properties. There were excellent simulation results for thermal cycling and for phase change experiments. The screening experiments also produced particularly good results because no cracks were observed in the test samples, large carbides typical with cast processes disappeared, and clear cellular structures were observed, which demonstrates an effective process. The project also accomplished a "first" for fabrication of a high carbon content alloy using an AM approach. The microscopic analysis confirming the formation of precipitates that strengthen the molecular structure of the alloy was a significant accomplishment for a new material with the potential for HT engine applications.

Reviewer 4:
Technical accomplishments are mainly in the development of the new LPBF HK30Nb alloy that was developed. The reviewer would like more information on whether this can be scaled up for cost effective manufacturing in large quantities.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This task is one of many tasks for early stage research for the PMCP and, as such, its success relies heavily on internal collaboration with the other ORNL researchers working on the other tasks and close coordination between the PIs to leverage data from one another's experiments. This task is already using microstructure data and microscopic analyses from two other tasks, which is an example of excellent coordination.

Reviewer 2:
This appears to be mostly an ORNL-centric project. However, the reviewer applauded the project for seeking industrial collaboration.

Reviewer 3:
Sufficient collaboration has been outlined in the report.

Reviewer 4:
The major weak point in this research project was the lack of industry partners. Also, the connection to the larger core program is unclear.

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

Reviewer 1:
The proposed future research aligns well with the project goals and DOE objectives. The research that was described appears appropriate, manageable, and with minimal risk.

Reviewer 2:
The proposed research seems to be sound for targeting a deeper understanding of the characteristics of the investigated alloys. Additional emphasis could be placed on the oxidation behavior in light of the target applications.

Reviewer 3:
The proposed future research is just a continuation of the current research into the next budget period. The proposed work follows a logical progression for obtaining additional data to be used with the models. There were no other challenges, barriers, or risks identified in the presentation or by the presenter, nor were any alternate development pathways addressed.

Reviewer 4:
It is unclear how the future research will lead to overcoming some of the stated barriers: higher efficiency engines resulting in increasingly extreme materials demands, costs of engine materials, development time, and scaling to commercialization.

Does the ICME effort only involve Calphad calculations? If not, what else is required to address relevant multi-length scale phenomena? Also, the reviewer asserted that the project seems interested in flow behavior, so how will ICME use a microstructure-based model to predict flow behavior, creep, fatigue, etc.? This cannot be done with thermodynamic predictions alone.

How do non-equilibrium solidification conditions impact mechanical behavior? How do small scale features like cells and precipitates affect macroscopic-scale behavior? How are single track alloy experiments leading to alloys that can be manufactured in a cost-effective manner on a commercial scale? Stainless steel is expensive. Why not try something like 4140?

According to the reviewer, another issue that is not addressed in this project that should be looked at is increasing part through-put with AM. Are 500,000 AM machines really needed to make 1 million parts (for example)? AM is not cost effective for high volume production and is currently limited to low volume applications.

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

Reviewer 1:
This task supports the overall VTO PMCP which directly supports the DOE objectives to meet requirements for materials needed to develop cost effective, highly efficient, and environmentally friendly next-generation, heavy and LD powertrains to include improved powertrain thermal efficiency, and increased power density resulting from high-strength and lightweight materials.

Reviewer 2:
New alloy development for the extreme conditions in powertrain applications supports the overall DOE objectives.

Reviewer 3:
The project results help to increase vehicle efficiency.

Reviewer 4:
Yes, the project supports the DOE objectives in the rapid development of high-performance metals for HT automotive engine applications.

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

Reviewer 1:
The approximate $200,000 per year for the 5-year performance period is considered sufficient to support the laboratory staff involved in the early stage research to develop a new, HT alloy using an AM approach.

Reviewer 2:
The resources are okay, but the project lacks industrial involvement to provide much-needed focus and direction.

Reviewer 3:
No limitations were reported.

Reviewer 4:
Resources appeared to be sufficient to complete the project objectives. The project appears to be ahead of schedule.

Reviewer 5:
The resources are okay, but the project lacks industrial involvement to provide much-needed focus and direction.

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 three reviewers evaluated this project.

Project Relevance and Resources

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

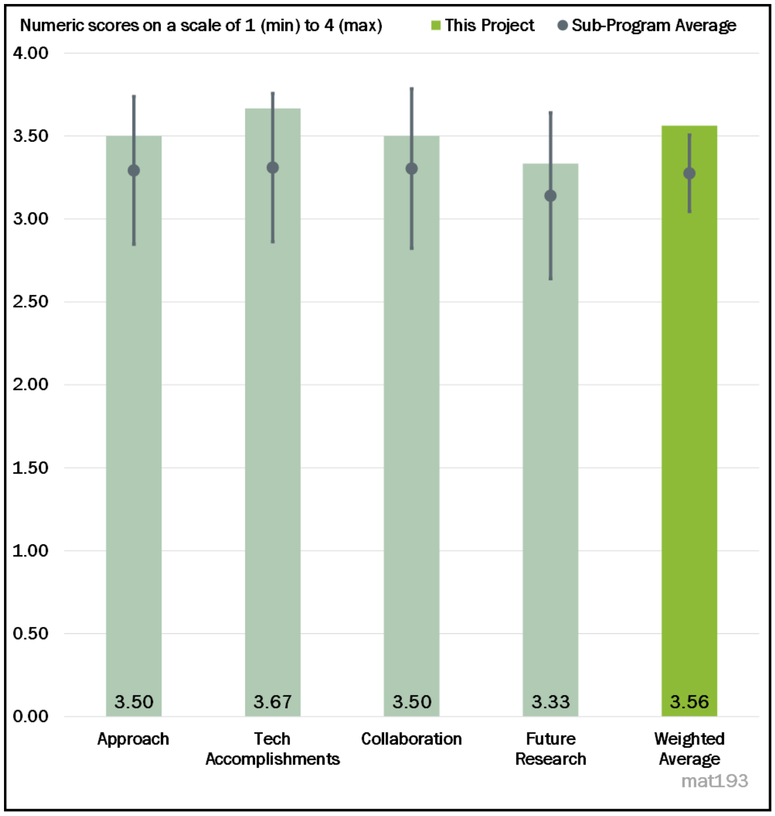

Figure 6-47 - Presentation Number: mat193 Presentation Title: Higher Temperature Heavy-Duty Piston Alloys Principal Investigator: Dean Pierce (Oak Ridge National Laboratory)

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 is fully satisfied with the approach taken by the project leaders.

Reviewer 2:

This project falls under Subtask 2A-2—Higher Temperature Heavy Duty Piston Alloys in Research Thrust Area 2—Cost Effective Higher Temperature Engine Alloys in PMCP. 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.

The FY 2019 budget was $250,000, and the FY 2020 budget is $200,000. The period of performance for this project is October 2018 – September 2023 and the work is 30% complete. The project aligns with the PMCP timeline.

Current HD diesel materials (HDD) piston steels (4140 and micro alloyed steel [MAS]) are not suitable for temperatures greater than 500°C have issues with oxidation and fatigue failure above 500°C. The objective of the project is to develop affordable, innovative, higher temperature piston alloys for this application. Developmental material targets for this application are as follows: design for operation between 600°C-800°C; yield strength of 400 MPa at greater than or equal to 600°C; ultimate tensile strength (UTS) of 525 MPa at greater than or equal to 600°C; cyclic oxidation resistance at peak temperatures, in air, and in a water vapor environment; long term microstructural stability; and affordable and manufacturable material.

Reviewer 3:
The approach described in the presentation is for the initial experimentation and does not directly address most of the DOE technical barriers described on the overview slides (higher power density, higher efficiency engines, cost of advanced engine materials, development time and cost of new materials, scaling new materials technologies to commercialization). The experimental approach described is well designed and feasible because it considers evaluation of existing commercial steels at very high temperatures, evaluation of novel and developmental martensitic steels, and the development of low, medium, and high Cr steels to develop novel alloying strategies that will meet requirements for HT engine components at lower costs. This is a good approach to address the technical barriers of accelerating alloy development time, improving elevated temperature strength, and maintaining oxidation resistance.

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 accomplishments were outstanding for exceeding the strength and oxidation resistance requirements for alloys above 550°C-600°C, which met the performance indicator described in the milestone chart. The results showed that the research was sharply focused on the critical barriers of improving strength at elevated temperatures for novel, low Cr alloys, and maintaining oxidation resistance at high temperatures for medium Cr alloys comparable to or better than commercial alloys.

Reviewer 2:
The reported achievements regarding the novel alloy developments are on par with the targets set out in the project plan.

Reviewer 3:
The team is on track to meet the projected material development targets. Research is attempting to find a lower cost material than the currently available high cost, high alloy content material. A variety of novel developmental martensitic steels with a range of Cr content will be investigated because lower Cr content is lower cost, but also lower performance. Oxidation is a problem with lower cost, lower Cr content steels. To establish a baseline for these materials, alloy 4140 was assessed and compared to commercial 12% Cr by weight (12Cr). 12CR has superior strength to alloy 4140; however, strength drops after long term thermal aging. Oxide intrusion and spallation in alloy 4140 is bad, but trying to avoid it leads to cracks which occurred at 500°C-550°C. 12Cr had unwanted breakaway Fe oxidation occurring at 550°C.

To address these issues, novel alloying strategies were employed, which may lead to improved oxidation resistance and strength at a limited extra cost. For the medium Cr alloys, the strength met targets as tempered. Using novel alloying strategies, the first iteration had good oxidation resistance but poor strength. The second iteration using a novel alloying strategy improved the strength and maintained oxidation resistance at 550°C, and a 600°C test is ongoing. The third iteration of a medium Cr alloy using novel alloying strategies is underway.

The team leveraged an activity performed under Thrust Area 4A to understand that the performance of integrating large Cr carbides into 12Cr steel provided minimal strengthening. It should be noted that the researchers cannot disclose the specific systematic alloy changes because of IP restrictions. All FY 2020 milestones have been completed and future milestones are on track to be completed on time.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
This task is one of many tasks for early stage research for the PMCP, and, as such, its success relies heavily on internal collaboration with the other ORNL researchers working on the other tasks and close coordination between the PIs to leverage data from one another’s experiments. This task coordinated to use microscopic

analyses from one other task, which is an example of good coordination within ORNL for the overall program. Other tasks may need to be coordinated, as this project progresses to leverage data from the other tasks.

Reviewer 2:
There is particularly good collaboration with partners providing sound and high-quality characterization techniques that exist.

Reviewer 3:
Collaboration across the three research laboratories is excellent. Collaboration is avoiding additional research costs. Industry participant is involved but not identified because of the IP agreement with the laboratory.

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

Reviewer 1:
The proposed research seems to be straight forward.

Reviewer 2:
A further understanding of the mechanisms resulting in improved strength and oxidation resistance in lower cost alloys is needed. Also, future research will scale up material to larger sizes. The team will investigate more thins and will utilize testing that is more relevant to industrial production and will begin to look for production partners.

Manufacturability of the alloys is still unknown; machinability testing will occur later in the project. There are also different melting practices for the baseline material. Cr alloys are vacuum arc re-melted (VAR), and alloy 4140 is air melted. These processes may impact the manufacturability and forgeability of these materials and will be investigated.

Reviewer 3:
The proposed future research is just a continuation of the current research into the next budget period. The proposed work follows a logical progression for obtaining additional data for scaling up the novel alloys to larger sizes for different types of testing, such as performing more relevant tests, including long term oxidation and elevated temperature fatigue testing simulating engine conditions. The proposed future work also includes establishing collaborations with industry partners to begin addressing barriers to commercialization of new alloys. The remaining challenges and barriers for increased oxidation performance of low and medium Cr alloys are achieving lower costs, fully understanding the mechanisms resulting in improved strength and oxidation resistance in those alloys, and investigating the manufacturability of developmental alloys by studying their melting practice and forgeability. All these efforts contribute to overcoming the DOE program challenges and barriers.

No risks or alternated development pathways were addressed, but the project approach tends toward a low or medium risk for new alloy development.

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

Reviewer 1:
This task supports the overall VTO PMCP, which directly supports the DOE objectives to meet requirements for materials needed to develop cost effective, highly efficient, and environmentally friendly next-generation HD and LD powertrains to include improved powertrain thermal efficiency, and increased power density resulting from high strength and lightweight materials.

Reviewer 2:
The work described helps to improve the efficiency of vehicle combustion engines.

Reviewer 3:
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.

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

Reviewer 1:
The approximate average cost of $300,000 per year for the 5-year performance period is considered sufficient to support the laboratory staff involved in the early stage research to develop a new HT, low-cost alloy for engine applications.

Reviewer 2:
This project is on schedule and the funding appears to be sufficient because all of the stated milestones have been completed on time (to date). Through the collaboration, the team avoided duplicate research and additional costs.

Reviewer 3:
No deficiencies in resources were mentioned by the project leaders.

Presentation Number: mat194
Presentation Title: Accelerated Design of Alumina-Forming, High Temperature Austenitic Alloys
Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

Presenter

Dongwon Shin, Oak Ridge National Laboratory

Reviewer Sample Size

A total of five reviewers evaluated this project.

Project Relevance and Resources

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

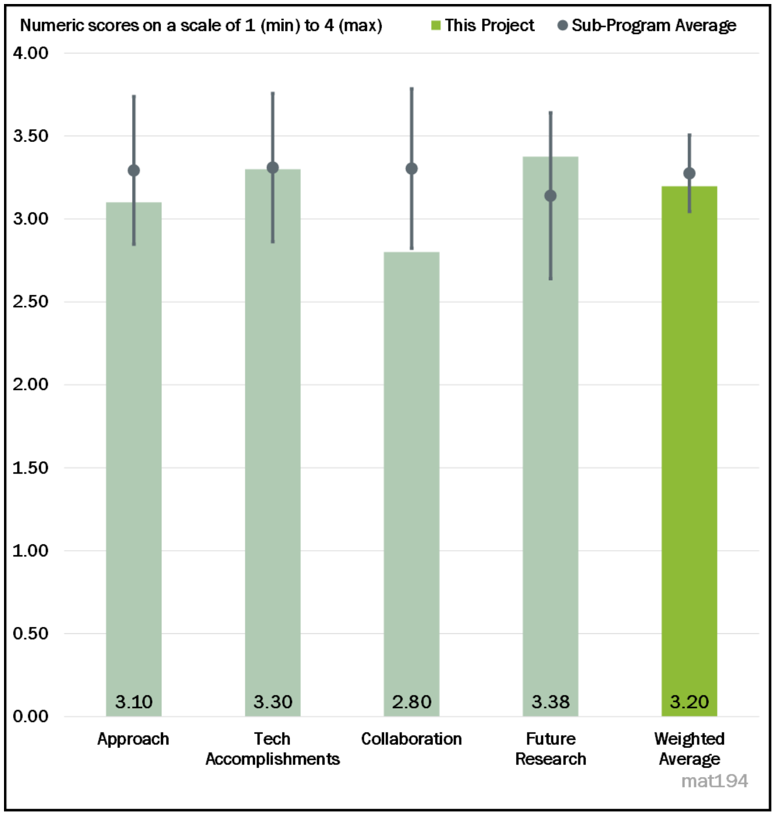

Figure 6-48 - Presentation Number: mat194 Presentation Title: Accelerated Design of Alumina-Forming, High Temperature Austenitic Alloys Principal Investigator: Dongwon Shin (Oak Ridge National Laboratory)

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:

The project uses Thermo-Calc software in concert with ML algorithms to predict the performance of alumina forming alloys. The ML approach was trained using data already available at ORNL. The approach was logical and sound.

Reviewer 2:

Two million hypothetical AFA alloy compositions have been explored. Since validation is virtual, it seems that no new alloys have actually been predicted and discovered since none have actually been made at any scale in a laboratory or elsewhere. This project needs to be coupled to a materials manufacturer who can validate the predictions by actually making the alloys. The project will have limited value if there is only laboratory-scale production in small quantities.

Reviewer 3:

The team made excellent use of ICME and ML to identify potential alloy concepts, but the reviewer would like to know who owns these potential new alloys for industrialization.

Reviewer 4:

It is very fortunate that a decade of creep data is available, and it is brilliant to think of using it with ML; however, the reviewer was disappointed in the limited amount of information being drawn from and augmented to the dataset on Slide 14. Also, the reviewer does not get any sense of the uncertainty error in the data and how uniform the data collection had been over 10 years. The high throughput data analytics approaches seemed to be outstanding and state of the art; however, the reviewer would like to have seen more data quality analysis for "garbage in, garbage out."

Reviewer 5:
It is difficult to assess the approach, as the project is in its early stages. It appears that only true validation of the model will occur when experiments are performed in the "predicted to be better AFA alloys." Overall, the approach appears to be fairly forced since the data set used to train the models was fairly extensive, especially for creep data. It is unclear if a physics-based approach that utilizes microstructural evolution in relation to creep performance would have yielded similar outcomes. This main criticism is of the approach and not of the effort. The work appears to be well designed, but feasibility is still unknown.

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:
Significant progress has been made, given that the project is only 1 month into its start. However, the most significant barrier will be to assess the accuracy of the model, which has not been done yet.

Reviewer 2:
The project has made significant accomplishments in its short duration. The trained ML algorithms have identified several alloy compositions with the potential to meet the target properties. This completes the key milestone for the project. The next task—probably as a continued work—is to produce some alloy compositions in the laboratory and perform tests to validate the performance.

Reviewer 3:
The project is a 1-year exploratory effort and 20% is complete. Targeted completion is September 2020. The team demonstrated ML accelerated design of hypothetical AFA-type alloys and leveraged 10 years of creep data. The team also coupled high throughput computational thermodynamics with ML and trained for prediction of creep resistance.

Reviewer 4:
Several alloy concepts were identified. The researcher will be interested in experimental results, well the results agree with the ML identified alloys, and is looking forward to next year's presentation.

Reviewer 5:
The results did not seem nearly as clear to the reviewer as the text indicated. Again, without understanding of uncertainty, the results are hard to judge, especially only 20% into the project. For example, the statement that the linear fits are showing good performance does not seem to be supported by the data. Also, the Larson-Miller Parameter (LMP) factor seems to be the main parameter explored.

Question 3: Collaboration and Coordination Across Project Team.

Reviewer 1:
There was outstanding collaboration within several divisions within ORNL (computational sciences and materials science) and the commercial software developer, Thermo-Calc.

Reviewer 2:
The only industrial collaborator is the Thermo-Calc software company. The reviewer does not see any industry collaborators of the end product and is not sure who owns these new alloys.

Reviewer 3:
It is hard to expect much from a relatively small project, but the use of a particular software seems an odd measure of collaboration.

Reviewer 4:
The collaboration partner activities are unclear. The PI appears to mainly be a user of the software and computing facility. The reviewer would like to know the specific contributions that have come from Thermo-Calc and the Compute and Data Environment for Science (CADES), other than accessibility. The collaboration role of ORNL will be clearer when the experimental components of the program are completed.

Reviewer 5:
The reviewer is not sure of the extent of collaboration with Thermo-Calc as a company as opposed to ORNL just using the software. This project needs to be coupled to a materials manufacturer who can validate the predictions by actually making the alloys.

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

Reviewer 1:
The reviewer is very pleased to see uncertainty quantification to assign error bars of ML predicted LMPs by considering the different number of features for a given ML model. The reviewer just wishes it had been done first.

Reviewer 2:
The proposed future research focuses on experimental validation and verification. These are necessary steps to establishing the fidelity of ML approaches, and thus the proposed future research is appropriate and effectively planned.

Reviewer 3:
Future research should focus solely on making one or more of the hypothetical alloys derived from the simulations and then demonstrating that as the as-made alloys with the desired creep properties. More details are needed on how a favorable alloy will be synthesized experimentally and then tested to demonstrate the desired creep properties. The reviewer would like clarification on who will do the testing.

Reviewer 4:
The project has ended.

Reviewer 5:
Limited details have been provided.

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

Reviewer 1:
This meets DOE's objective for improved engine efficiencies for vehicles for fuel savings. One approach is to operate the engines at HTs and pressures, which requires HT alloys with enhanced mechanical properties (i.e., creep). In this regard, this project provides a ML approach to identify alloy compositions that have the potential to meet the desired target properties.

Reviewer 2:
If the team is successful in predicting the creep performance of new, never previously developed alloys is shown, the research will have made a significant impact on the community.

Reviewer 3:
The development of lightweight, creep resistance alloys supports the overall DOE objectives.

Reviewer 4:
Improved HT properties of materials are critical to pushing engine efficiencies higher.

Reviewer 5:
HT materials are related to energy efficiency and reducing development time is related to industrial competitiveness.

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

Reviewer 1:
The resources seem well matched to the tasks being undertaken.

Reviewer 2:
The resources appear to be sufficient to complete the milestones in a timely fashion.

Reviewer 3:
Computational resources were adequate for the project. In addition, the data set for the alumina forming alloys were available and used for training of the ML models.

Reviewer 4:
The reviewer assumed resources are okay, as no issues were raised, but no details on the plan and budget were provided.

Reviewer 5:
More details are needed on resources required to synthesize the most favorable alloy or alloys from the model predictions.

Acronyms and Abbreviations

2-D	Two-dimensional
3-D	Three-dimensional
4X	4X Technologies
12Cr	12% chromium by weight
µ DIC	Microscopic level DIC
A356	356 aluminum
ABL	Acrylonitrile butadiene lignin
ACE	Advanced combustion engine
ACP	Advanced Carbon Products
AFA	Alumina-forming austenitic
AGC	Aluminum graphene composite
Al	Aluminum
$Al_{10}SiMg$	Aluminum-silicon-magnesium
Al_2Cu	Aluminum-copper
Al_2O_3	Aluminum oxide
AM	Additive manufacturing
AMC	Aluminum matrix composite
ANL	Argonne National Laboratory
APS	Atmospheric Plasma Solutions
APS	Advanced Photon Source
APT	Atom probe tomography
ASM	American Society for Metals
AZ31B	Aluminum and zinc magnesium alloy
$BaTiO_2$	Barium titanate
Bio-ACN	Bio-acrylonitrile
Ca	Calcium
CAD	Computer aided design
CADES	Compute and Data Environment for Science

CAE	Computer-aided engineering
CALPH	CALculation of PHAse Diagrams
Ce	Cerium
CE	Coulombic efficiency
CF	Carbon fiber
CFD	Computational fluid dynamics
CFRC	Carbon fiber reinforced composites
CFRP	Carbon fiber-reinforced polymer
CFTF	Carbon Fiber Technology Facility
CNT	Carbon nanotube
CO_2	Carbon dioxide
CO_2-AP	CO2-atmospheric plasma
CPEC	Close proximity electromagnetic carbonization
CRADA	Cooperative research and development agreement
CRS	Cold-rolled steel
Cr_2O_3	Chromium (III) oxide
CTE	Coefficient of thermal expansion
CTP	Coal tar pitch
Cu	Copper
DARPA	Defense Advanced Research Projects Agency
DFT	Density functional theory
DIC	Digital image correlation
DOE	U.S. Department of Energy
EDX	Energy-dispersive X-ray
EG	Electrogalvanized
EMSL	Environmental Molecular Science Laboratory
EV	Electric vehicle
Fe	Iron

FE	Finite element
FEA	Finite element analysis
FEM	Finite element analysis
FSE	Friction stir extrusion
FSP	Friction stir processing
FSW	Friction stir welding
FY	Fiscal year
GHG	Greenhouse gas
GM	General Motors
H2O	Water
HAADF-STEM	High annular dark field scanning transmission electron microscopy
HCF	High-cycle fatigue
HD	Heavy duty
HDD	Heavy duty diesel
HEDM	High-energy diffraction microscopy
HCP	High performance computing
HP-RTM	High-pressure resin transfer molding
HT	High temperature
IACMI	Institute for Advanced Composites Manufacturing Innovation
IACS	International Annealed Copper Standard
lb	Pound
ICE	Internal combustion engine
ICME	Integrated computational materials engineering
IDZ	Interdiffusion zone
ILSS	Interlaminar shear strength
IP	Intellectual property
kp	Parabolic rate constant
ksi	Kilopound per square inch

KWN	Kampmann-Wagner
LD	Light duty
LMP	Larson-Miller Parameter
LPBF	Laser powder bed fusion
MAS	Micro alloyed steel
MD	Molecular dynamics
MDF	Manufacturing Demonstration Facility
Mg	Magnesium
$MgCO_3$	Magnesium carbonate
MgO	Magnesium oxide
MIT	Massachusetts Institute of Technology
ML	Machine learning
mm	Millimeter
MMC	Metal-matrix composites
MPa	Megapascals
Msi	Million pounds per square inch
NERVE	Networked Elements for Resin Visualization and Evaluation
Ni	Nickel
NiCr	Nichrome
NO_x	Oxides of nitrogen
O_2	Oxygen
OEM	Original equipment manufacturer
ORNL	Oak Ridge National Laboratory
PAN	Polyacrylonitrile
PF	Phase field
PI	Principal Investigator
PMCP	Powertrain Materials Core Program
PNNL	Pacific Northwest National Laboratory Pacific Northwest National Laboratory

PP	Polypropylene
ppm	Parts per million
PµSL	microstereolithography
psi	Pounds per square inch
PSU	Penn State University
Q	Quarter
Ra	Roughness average
R&D	Research and development
ReaxFF	Reactive force field
REE	Rare earth element
RIM	Reaction Injection Molding
ROI	Return on investment
RSW	Resistance spot weld
RT	Room temperature
RTM	Resin transfer molding
s	Second
SAE	Society of Automotive Engineers
SBIR	Small Business Innovation Research
SECCM	Scanning electrochemical cell microscopy
SEED	Seeking Educational Equity and Diversity
SEM	Scanning electron microscope
ShAPE™	Shear Assisted Processing and Extrusion
SiC	Silicon carbide
SIMS	Secondary ion mass spectroscopy
SPI	Stochastic pre-ignition
SPR	Self-pierce rivet
SPS	Single-prolonged stress
Sn	Tin

SNS	Spallation Neutron Source
SRI	Southern Research Institute
SStAC	Stainless steel alloy corrosion
STTR	Small Business Technology Transfer
SuRF	Scale-up Research Facility
T6	Temper 6
TCR	Temperature coefficient of resistance
TEM	Transmission electron microscopy
Tg	Glass transition temperature
Ti	Titanium
TiB_2	Titanium diboride
TiO_2	titanium dioxide
TL	Trifunctional linker
TRL	Technology readiness level
TuFF	Tailored universal Feedstock for Forming
UCLA	University of California, Los Angeles
UD	University of Delaware
µm	Micrometer
UM	University of Michigan
USW	Ultrasonic welding
UTK	University of Tennessee, Knoxville
UTS	Ultimate tensile strength
UW	University of Wyoming
VAR	Vacuum arc re-melting
VIM	Vacuum induction molding
VT	Virginia Polytechnic and State University
VTO	Vehicle Technologies Office
WRI	Western Research Institute

WPI	Worcester Polytechnic Institute
XPS	X-ray photoelectron spectroscopy
YS	Yield strength
Zn	Zinc
ZnPhos	Zinc phosphating
ZrO_x	Zirconium sub-oxide