Carbon Fiber Technology Facility

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Project ID: CPS# 25349

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Overview

The Carbon Fiber Technology Facility (CFTF) serves as a national resource to assist industry in overcoming the barriers of carbon fiber cost, technology scaling, and product and market development.

CFTF is intended to be the bridge from R&D to deployment and validation of low-cost carbon fiber

	FY16	FY 17	FY18	FY 19
Total Budget	5.5 M	5.3 M	6.0 M	6.0 M
VTO	1.5 M	1.3 M	1.0 M	1.0 M
AMO	4.0 M	4.0 M	4.0 M	4.0 M
Other			1.0 M	1.0 M

Focused on demonstrating the scalability of low-cost carbon fiber

- 42,000 ft^2 facility with production capacity of 25 tons/year of fiber from multiple precursors in various forms

Vehicle Lightweighting

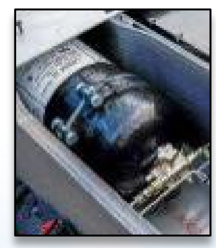
Reduce vehicle weight by using carbon fiber throughout body and chassis

Wind Energy

Build turbine components and longer blade designs for applications in wind energy

Gas Storage

High-strength, lightweight pressure vessels for storage of gas



Recreational Equipment

Next-level performance for sporting goods and recreational equipment

Projective Objective

Core Research and Development

Leveraging ORNL's Science Capabilities to Solve Challenges in carbon fiber and composites manufacturing.

Industry Collaborations

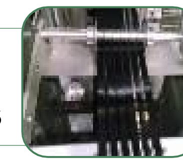
Cooperative research to develop and demonstrate low cost CF manufacturing to reduce the cost promoting and expanding the use of CF and its composites in clean energy applications

Education and Training

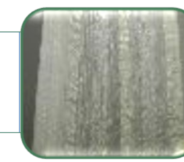
Internships, academic collaborations, workshops, training programs, and course curriculum for universities and community colleges.

The Carbon Fiber Technology Facility

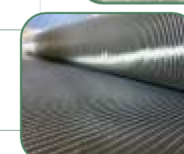
1. Establish and perform collaborative R&D projects to reduce technical uncertainties in CF manufacturing process



2. Investigate potential alternative carbon fiber precursors



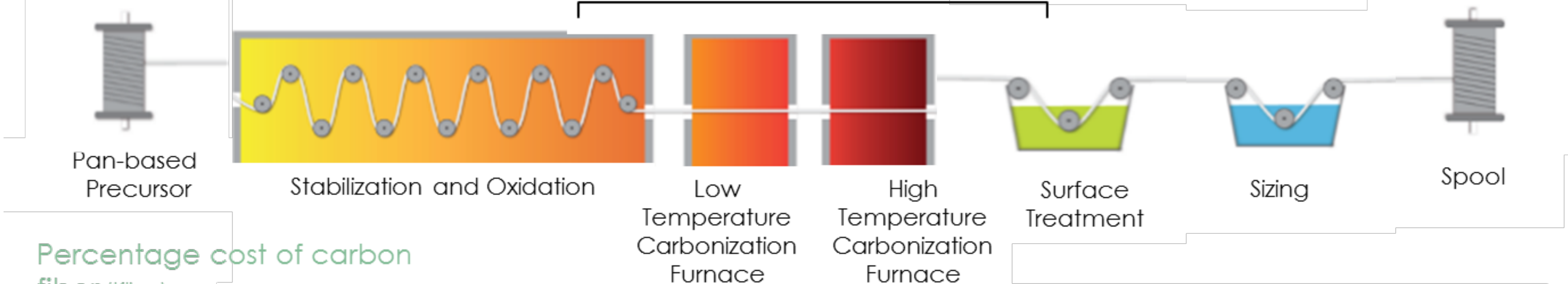
3. Investigate carbon fiber intermediate forms and technical challenges in composite applications



4. Establish artificial intelligence-based framework and correlate process data to product characteristics

5. Investigate and develop in process measurement, sensing and control methods

Technical Innovation



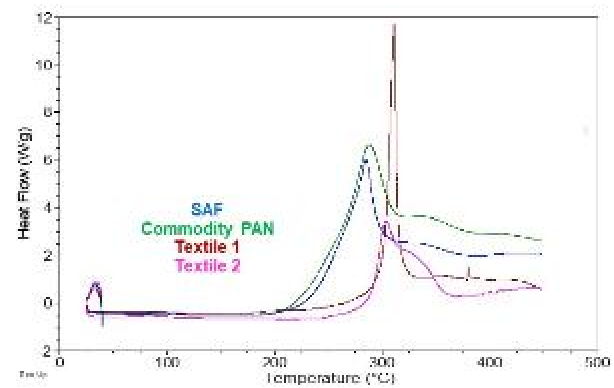
Percentage cost of carbon fiber (Kline)

~50%	~40%	~10%
Precursor	Conversion	Primary finishing and packaging

Percentage energy of carbon fiber conversion (Das)

			Waste Gas Abatement		
Conventional Carbon Fiber	~80%	~13%	~18%	~14%	~3%
Textile Carbon Fiber	~70%	~10%	~17%	~0%	~3%

Intellectual property developed around scalable process for producing low cost carbon fiber.
Differential scanning calorimetry (DSC) analysis of the precursors show potential difficulty in stabilizing textiles!
ORNL team successfully overcame that deficiency during thermal oxidation of the precursor fibers



Open

Technical Approach

Material Identification

- Conversion Yield
- Precursor Cost
- Oxidation Time
- Availability
- Precursor Microstructure
- 10s grams - bench scale

Fiber Evaluation CF Line

- Capacity for 1 - 2 tows
- 20k – 80k filaments
- Small Volume
- 100s grams

Pilot scale CF Line

- Capacity for 1-5 tows
- 5k -80k filaments
- Preferred tow size ≥ 3k
- 100s grams – 1 kg

Scale-up CF Line

- Capacity for 24 – 24K tows
- 3k – 80k tows
- 25 tons/yr
- Highly Flexible instrumented line

Carbon Fiber Forms

Low, Standard and Intermediate Modulus Carbon Fiber

•Provide sample quantities with favorable properties to industrial partners for testing based on DOE approval

Collaborative Joint-Industry Projects

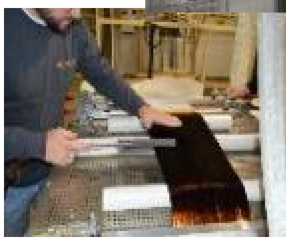
- Integrated approach to low-cost carbon fiber manufacturing R&D
- Individual R&D projects
- Collaborative R&D consortia
- Early-stage R&D and technolog partnerships
- Industry Collaborations

Ever Growing Partnerships: Integrating the AM Supply Chain

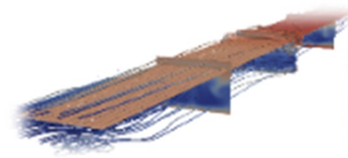
Results and Accomplishments

Reducing Technical Uncertainties project examples

Developing Precursor Splicing technique for Precursor to ensure continuous production

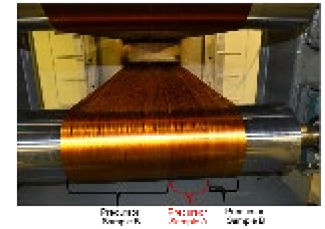


Splicing Method for heavy tows
Team: ORNL



- Develop a three-dimensional, multi-physics computational model for faster, energy efficient process

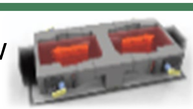
3-D Multi-physics model for carbonization process
Team: ORNL – (Srikanth Allu, Srdjan Simunovic)
Harper International



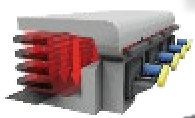
Carbon Fiber A		
Property	Precursor Sizing Type 1	Precursor Sizing Type 2
Tensile Strength (ksi)	457	369
Tensile Modulus (msi)	39	36
Elongation (%)	1.18	1.06
CF Density (g/cc)	1.7651	1.7573

Impact of Precursor surface finish on Processability and properties
Team: ORNL-Litzler-Licensee

- *center-to-end parallel flow



- *Down-flow



- *cross-flow air distribution

Flow Distribution Impact/design parameters

Carbon Fiber A		
Property	Parallel	Crossflow
Tensile Strength (Ksi)	314.6 ± 18.3	360.2 ± 15.1
Tensile Modulus (Msi)	35.9 ± 0.4	37.3 ± 1.0
Elongation (%)	0.89 ± 0.07	0.98 ± 0.4
CF Density (g/cc)	1.7478 ± 0.0024	1.7565 ± 0.0090
Comments	• Difficulty in processability • Lots of fuzz • Poor wet out of fiber • Tensile Failure not acceptable • Poor quality carbon fiber	

Team: ORNL-Litzler-Licensee

- Preliminary Trials showed 32% reduction in Oxidation time

Team: ORNL-Litzler

- Poor quality precursor = poor quality carbon fiber
- Improve fiber quality for better translation in composites

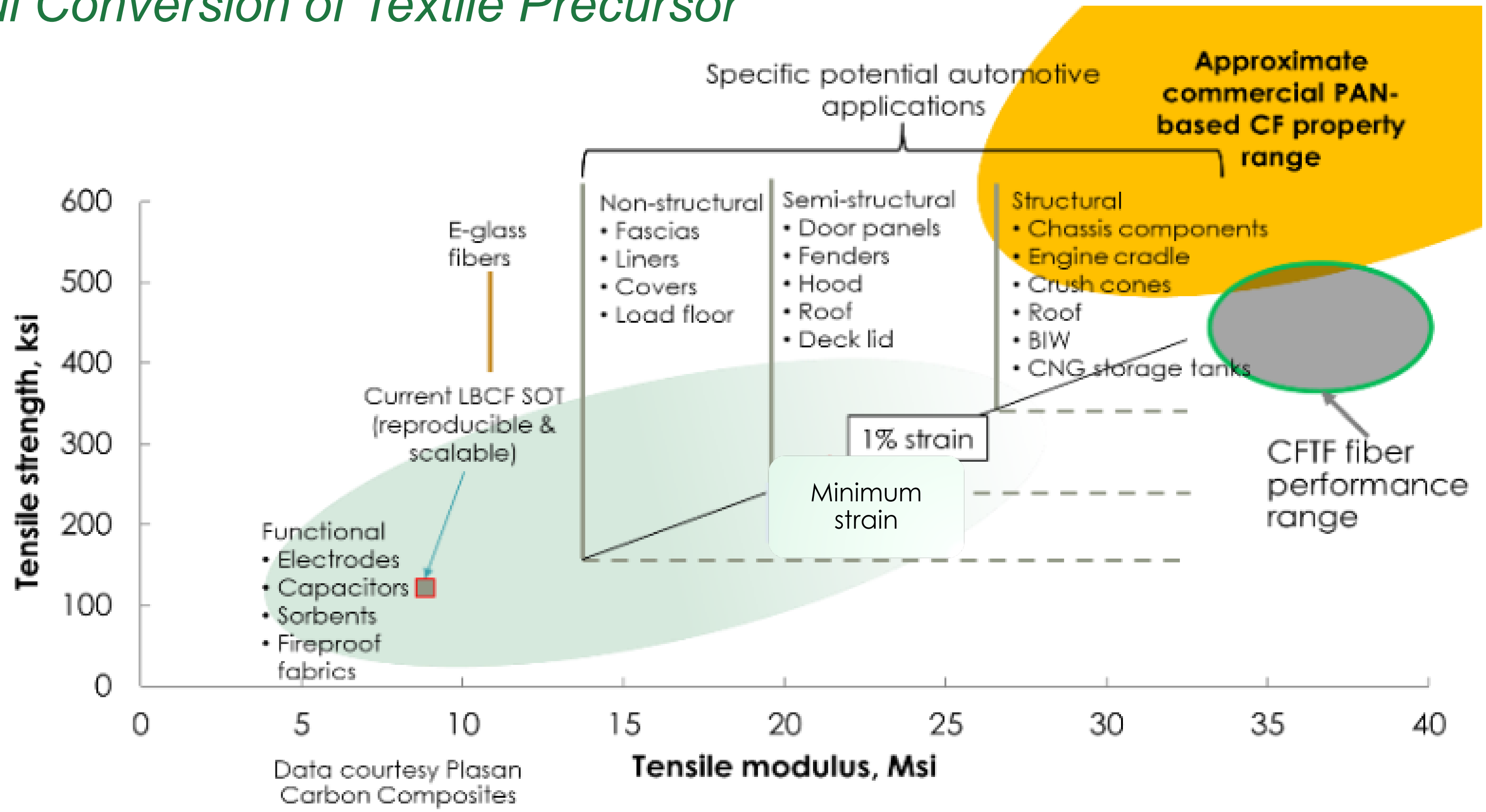
Team: ORNL-Litzler-Licensee

Impact of Precursor Packaging on processability and quality of fiber
Team: ORNL-Litzler-Licensee

*https://calitzler.com/complete-carbon-fiber-lines/complete-carbon-fiber-line-equipment/oxidation-ovens/

Results and Accomplishments

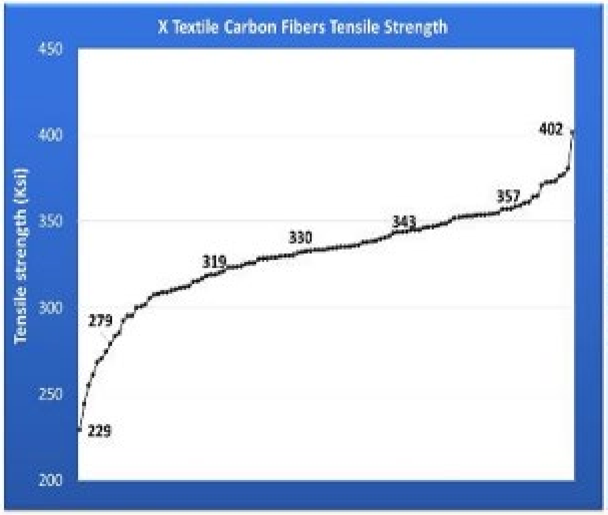
Successful Conversion of Textile Precursor

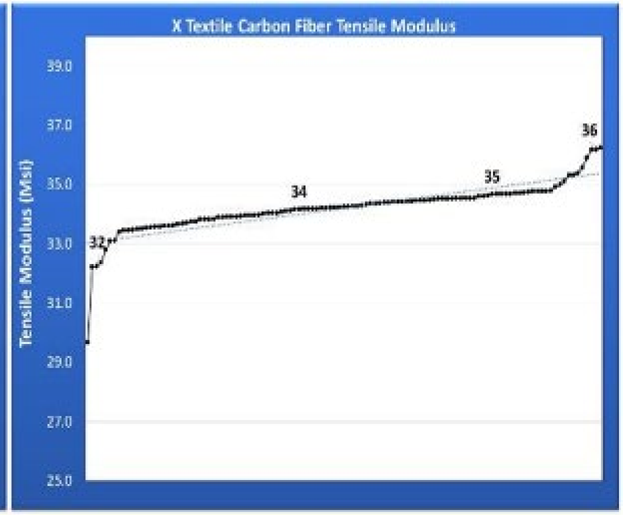


- Carbon fiber varies in tensile modulus (determined as deformation under strain) and tensile, compressive and fatigue strength.
- CFTF have > 30 varieties of textile precursors from International Sources.
- CFTF successfully developed low, standard, and intermediate carbon fiber using textile-based precursor
  - **Low mod. (less than <32 Msi)**
  - **Standard mod. (33 to 36 Msi)**
  - **Intermediate mod. (40 to 50 Msi)**

Results and Accomplishments

Alternative Precursors and associated conversion



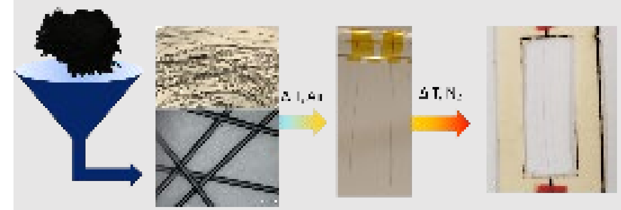


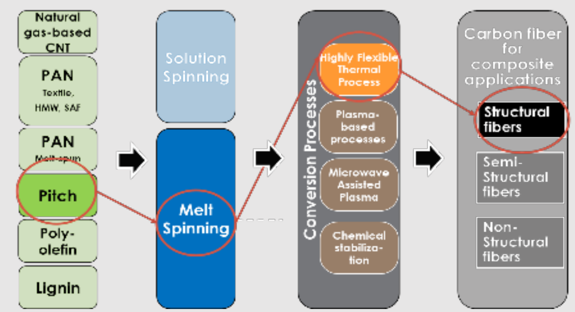
- CFTF have > 30 varieties of textile precursors from International Sources.
- Most recent textile precursor was converted in 24hrs.
- Highest Tensile properties obtained are 402 Ksi, and 36 Msi tensile strength and tensile modulus, respectively.

Example of future alternative precursor

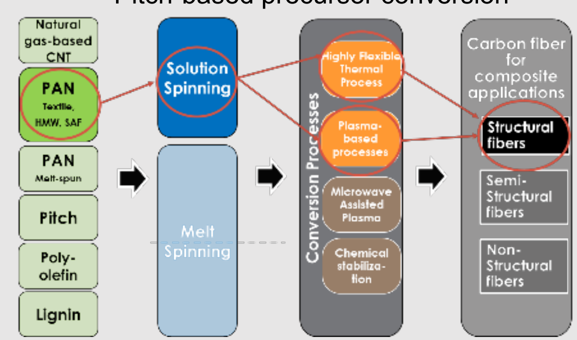
Produce and validate high modulus carbon fibers from high-yield polyaromatic hydrocarbon precursors.
Mesophase Pitch Fibers

Spinning and Carbonization of Mesophase Pitch Fiber ORNL – PI -James Klett





Pitch-based precursor conversion



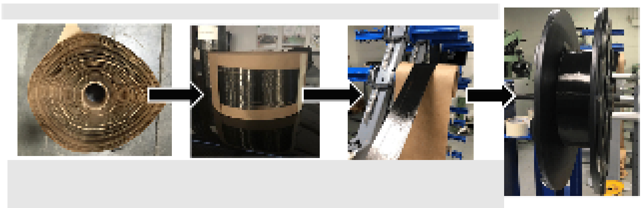
Textile-based precursor conversion

DOE Webinar to US Drive partner companies on 12/4/2018 "Carbon Fiber R&D progress and technology status towards validation and deployment for automotive application – Amit Naskar & Merlin Theodore

OAK RIDGE National Laboratory

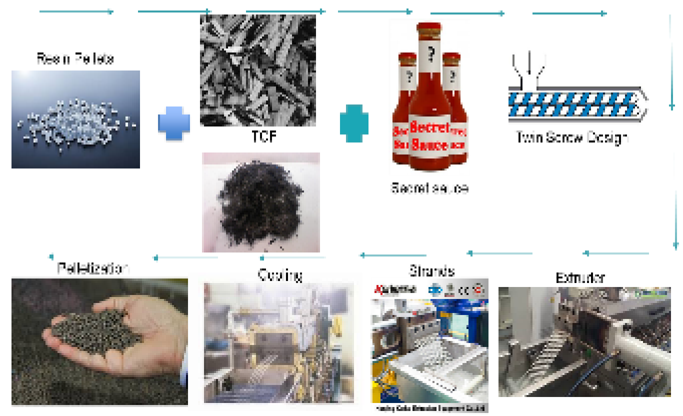
Results and Accomplishments

Intermediates– Joint Industry Project examples



Develop commercial relevant Packaging for TCF

ORNL – IACMI -Mc. Coy Machinery - Chomarat – Montefiber - UT



Pelletization & Compounded Textile Carbon Fiber

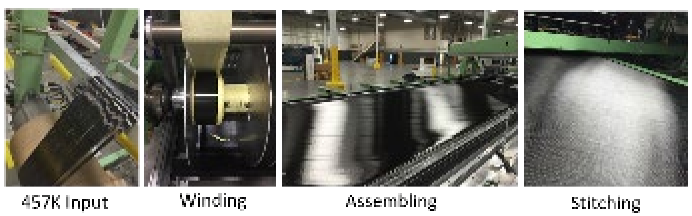
ORNL-IACMI –Techmer

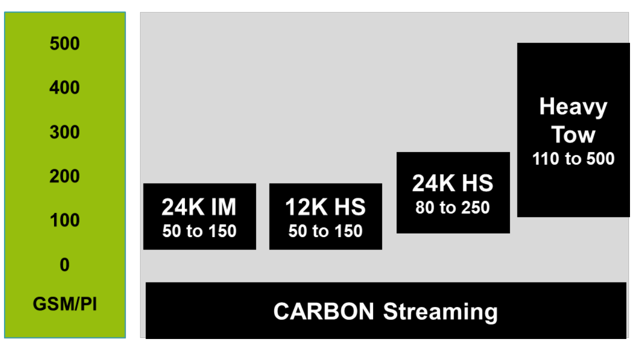
- Techmer compounded PA66 with 10%, 25%, and 40 % LCCF

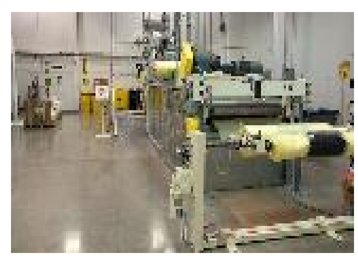
TCF in Prepreg production

ORNL-IACMI –Prolink -CDI

Joint project – CFTF 18-015







Sheet Molding Compound Reinforced by Recycled or Textile Carbon Fibers

ORNL/UTK, Adherent Technologies-AOC-Ashland, Continental Structural Plastics-Huntsman-IDI Composites-Michelman-Vertigo-Volkswagen

Develop Chopping Equipment for chopping TCF at various length with various Sizing

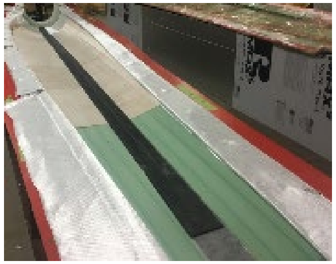
ORNL- IACMI – CRTC-DM&E-Cygnet Texkimp

- Project# TF18-010

Results and Accomplishments

Composites – Joint Industry Project examples

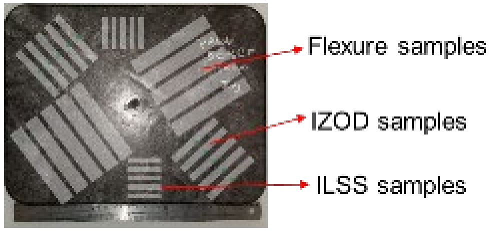
Pultrusion of carbon fiber wind turbine spar caps has demonstrated cost reductions and improved performance versus infusion.



Use of textile carbon fibers (TCF) will lower that further. Conventional pultrusion is not designed for large tow form typical of the TCF.

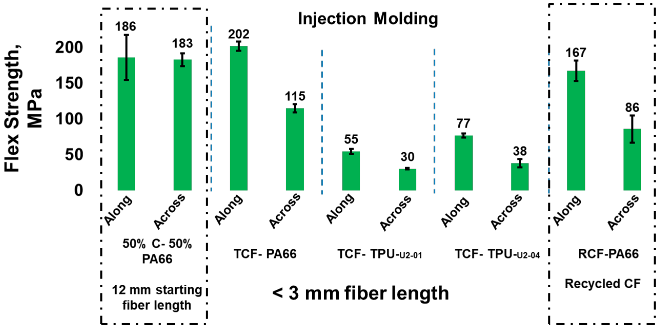
Team: TPI Composites, Montefibre, Huntsman, NREL, ORNL, UTK

Injection molding ➡ Battery Tray



Textile Thermoplastics Battery Tray Flex Molds

Team: Honda, Valley Industries-IACMI-ORNL -UT



Textile carbon fiber Performance Database (Coupon Testing) use in design, modeling and application development

Team: ORNL CFTF-IACMI-ORNL MDF-UT

Bike Form produced using Non-crimp textile carbon fiber fabric and Elium Resin via compression molding

Team ORNL-IACMI-Chomarat

Fenders

75 secs cycle time

https://www.youtube.com/watch?v=NRk_v3fPyCI&t=163s

		40% CF in PA66		10% CF in PA66	
Property	Units	Commercial CF	CFTF Fiber	Commercial CF	CFTF Fiber
Tensile Strength @ Yield	Psi	37,000	28,100	21,700	19,800
Tensile Elongation @ Break	%	1.8	1.0	2.4	2.2
Flexural Strength	Psi	37,300	37,000	30,000	28,500
Flexural Modulus	Psi	3,900,000	3,840,000	1,000,000	1,260,000
Notched izod	ft-lb/in	1.39	1.01	0.50	0.60
HDTUL @ 264 psi	ºF	489	484	479	468
Surface Resistivity	ohms/sq	2.20E+03	1.10E+04	3.20E+05	1.99E+12

Injection Molded Saturn Fenders using

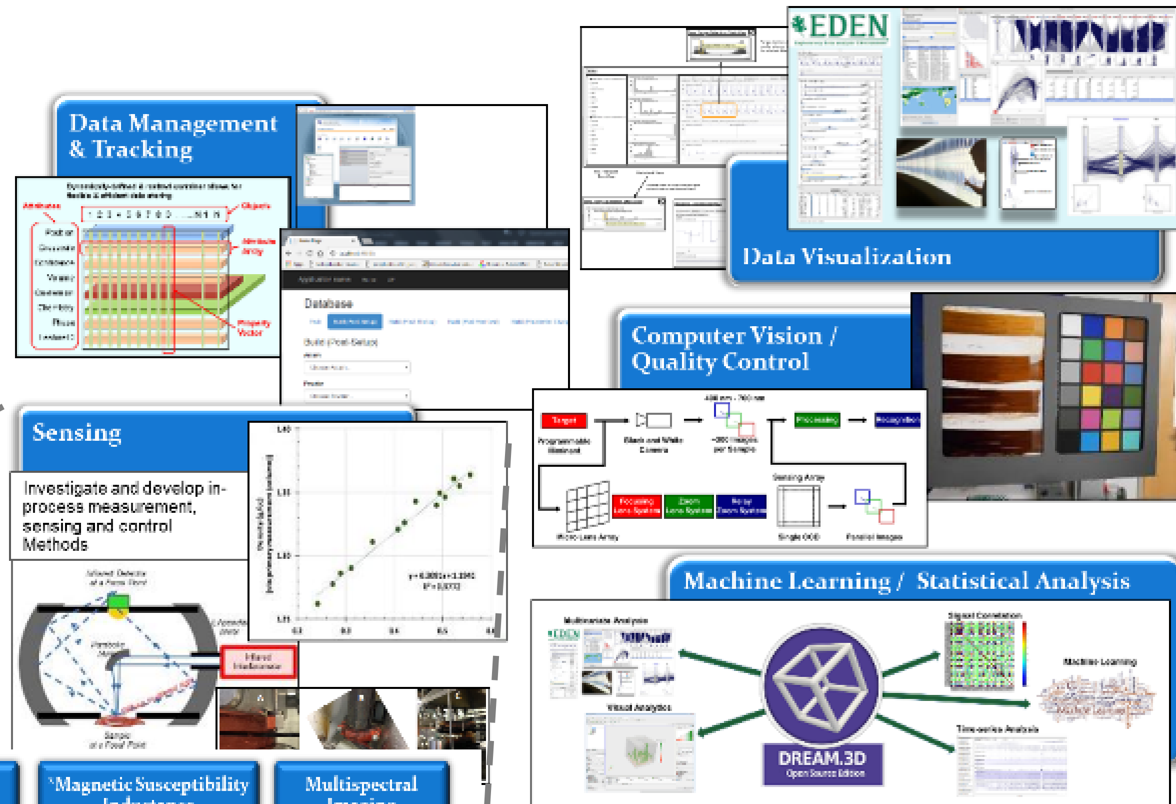
Team: ORNL-IACMI-Techmer-MSU

Car hood Mold Printed using the BAAM System

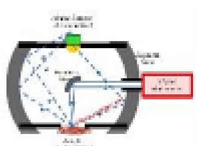
Textile carbon Fiber in Additive Manufacturing

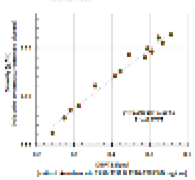
Team ORNL-CFTF-Techmer-MDF

Results and Accomplishments



DRIFTS

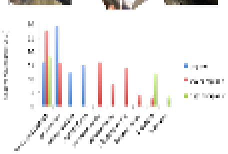




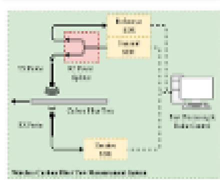
The Fourier Transform Infrared (FTIR) spectroscopy techniques will enable measurement of the specific fiber chemistry associated with crosslinking and cyclization reactions characterizing the chemical bonds present in the fiber material

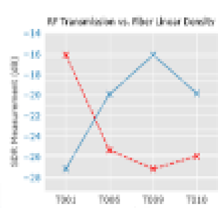
OFF-GAS Measurements

Off-gas measurements Extractive samples will be analyzed via standard methods including MS, FTIR and GCMS to identify the control species, which in process-control applications can be monitored via the real-time analytical techniques or other in-situ sensors.



CF Resistivity





This work explores the use of software defined radios (SDR) as a low-cost method to wirelessly probe the carbon fiber tow to determine material properties of the tow

Magnetic Susceptibility Inductance

Relationship between degree of oxidation and crosslinking is expected to be observable through magnetic susceptibility measurement. Value of magnetic susceptibility of fiber tow can be measured and compared with a strength-related set point

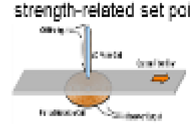
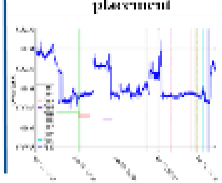
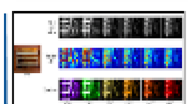
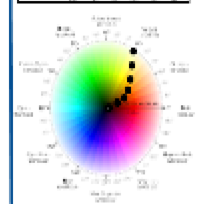


Illustration of component placement



Multispectral Imaging





In-line and off-line multispectral measurements of the fibers, to capture the colorimetric information used by operators to estimate the quality of the fiber along the production line

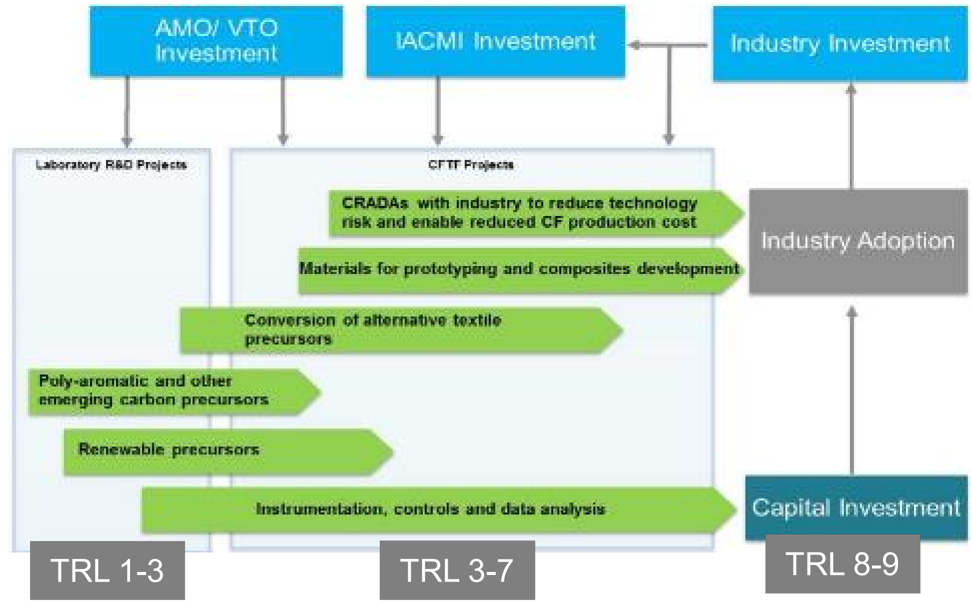
Data Analytic Framework enable process variables to be tuned and optimized during manufacturing improving quality, efficiency, throughput, better process capability & control thus reducing energy usage and scrap.

*"Wireless Measurement of Carbon Fiber Tow Properties Using Software Defined Radio" - Publication ID 100515

Transition

Carbon Fiber Industry Collaboration

- *Over 50 Technical Collaborations*
- *FLC Technology Transfer Award*
- *New Material Suppliers*
- *4 Licensees for Textile precursor to CF*
- *CFTF Tech Interns to Licensee employees*
- *Three CRADAS*
- *Mission and Capabilities*
  - *Industries are able to adopt new opportunities using CF*
  - *Enhance their processes and capabilities, thus expand their market growth.*



December 2015 – 2 - Patents application
Method of Producing Carbon Fibers from Multipurpose Commercial Fibers, (ORNL ID 3583), Pending U. S. Patent Application

June 2016 – ORNL, License Selection
US Job Creation
US Wealth Creation
Deployment of Clean Technologies
Company ability to develop and market a new product or service
Company's commitment to manufacture in the US

Aug. 2016 – 6 CFTF staff members hired by Licensee

Aug. – Oct. 2016 – ORNL, License #1 executed; License #2 executed

December 2016 – Technology Non-Provisional Patent application
Method of Producing Carbon Fibers from Multipurpose Commercial Fibers, (ORNL ID 3583), Pending U. S. Patent Application

January 2017 – ORNL, License #3 executed

May 2017 – 1st CRADA Approval
Company has an option to negotiate up to an exclusive license for patentable inventions created by ORNL staff under a CRADA

June 2017 – ORNL, License #4 executed

Oct. 2017- Feb. 2018 – 2nd CRADA Approval; 3rd CRADA Approved

February 2018 – Federal Laboratory Consortium Excellence in Technology Transfer Award

April –May 2018 – Publications Generated

June 2019- present – 4th CRADA In progress; 3 new capabilities installed; Patent claims allowed

Questions


CARBON FIBER
TECHNOLOGY FACILITY
OAK RIDGE NATIONAL LABORATORY
93 PALLADIUM WAY