GATE Center of Excellence at UAB for Lightweight Materials and Manufacturing for Automotive, Truck and Mass Transit

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Birmingham, Alabama

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Project ID# TI026

Project No: DE-EE-0005580
Program Manager: Adrienne Riggi

GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

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Project Summary

Timeline

Project Start - Oct 2011
Project End – Sep 2016
55% complete

Budget

Total project: $750,000
DOE portion: $600,000
University Cost Share: $150,000
$447,420 DOE
$325,000 Expended
55% complete

Barriers

- Limited information on advanced materials database
- Lack of high temperature properties

Partners

- ORNL
- MIT-RCF
- Owens Corning
- Polystrand, PPG
- CIC, Canada

Relevance and Goals

Overall VTP Goals

- "Development and validation of advanced materials and manufacturing technologies to significantly reduce automotive vehicle body and chassis weight without compromising other attributes such as safety, performance, recyclability, and cost."

DOE GATE Goal

- "To provide a new generation of engineers and scientists with knowledge and skills in advanced automotive technologies."

The UAB GATE Goals are focused on the above VTP and GATE goals

- Train and produce graduates in lightweight automotive materials technologies
- Structure the engineering curricula to produce specialists in the automotive area
- Leverage automotive related industry in the State of Alabama
- Expose minority students to advanced technologies early in their career
- Develop innovative virtual classroom capabilities tied to real manufacturing operations
- Integrate synergistic, multi-departmental activities to produce new product and manufacturing technologies for more damage tolerant, cost-effective, and lighter automotive structures.

Materials Processing and Applications Development (MPAD) Center at UAB – The research focus is on applications development with rapid transition to industry

- 20,000 sq.ft of industry scale facilities
- Rapid technology transition to industry – defense, transportation, infrastructure, aerospace and marine
- Strong industry partnerships with materials suppliers, integrators and end users; more than 20 active NDA's
- Partnerships with federal & state agencies, and national labs (NSF,DOE, DOD etc)

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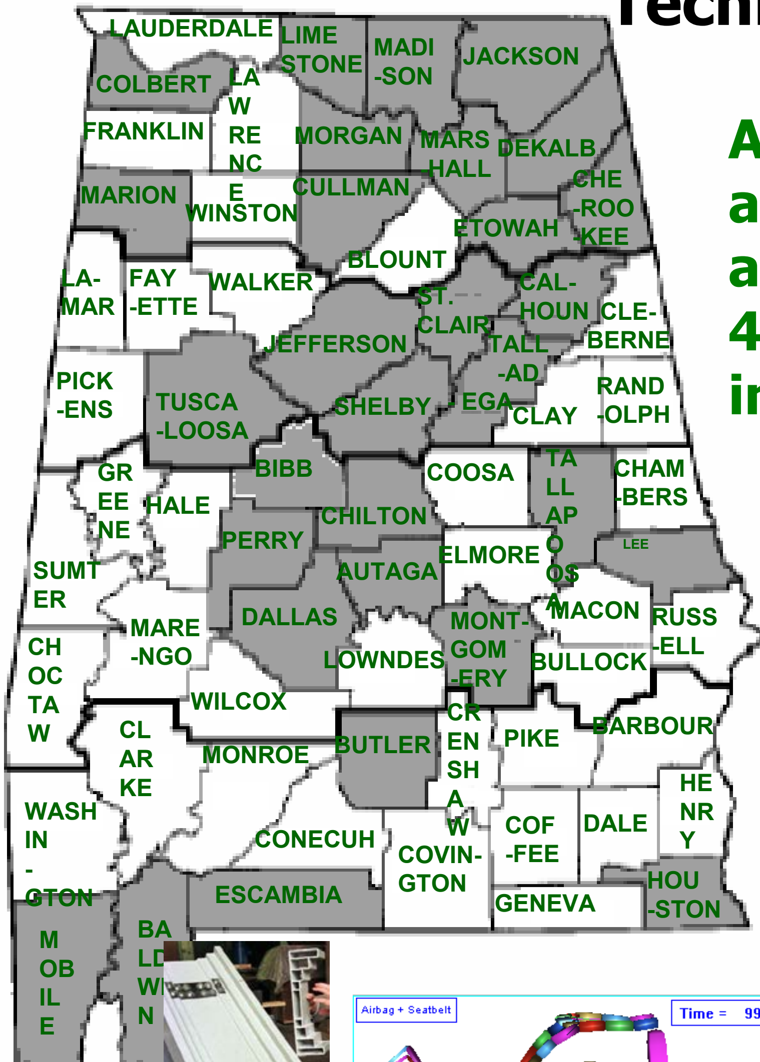
Core Competencies

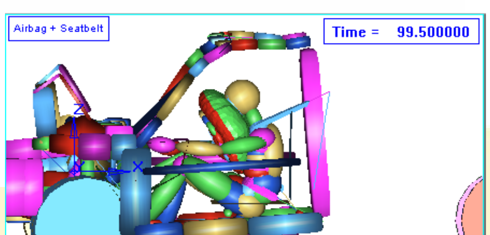
- Technologies for lightweight composites and metals
- Industrial scale facilities
- Engineered composites and metals design, development, prototyping & manufacture
- Extrusion-compression (LFTs), Pultrusion, Wet-laid, Compression molding, Thermoforming, Vacuum Infusion
- Solidification & casting, Lost foam casting, Ductile steel, aluminum and magnesium
- Small, medium and high volume production flexibility
- Commercialization outlet – R&D to commercial transition
- Training, education and outreach

Automotive Industry Impact in the State of Alabama – UAB DOE Graduate Automotive Technology Education (GATE)



Alabama has a rapidly growing automotive industry. Since 1993 the automotive sector has created more than 45,000 new jobs and $8 billion in capital investment in Alabama.

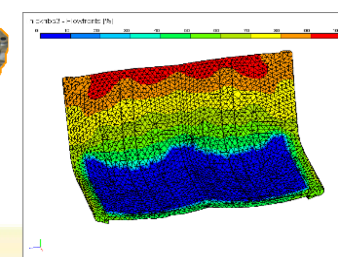
- Training students in advanced lightweight materials and manufacturing technologies.
- Design and manufacturing of future generation transportation, including automobiles, mass transit and light, medium and heavy trucks.



Modeling of crash & protective padding


High speed computational facility


Automotive castings


Process modeling

UAB GATE Center for Lightweight Materials and Manufacturing for Automotive and Transportation

Materials Science & Engineering/MPAD
Lightweight Composites and Castings – Materials and Manufacturing R&D

Mechanical Engineering
High-fidelity modeling and simulation; predictive Engineering, material models

Biomedical Engineering
Crash & injury studies, Studies for protection using lightweight advanced materials

Civil and Environmental Engineering
Highway crash barrier, road safety, pedestrian collisions, Transportation infrastructure

ACADEMIC PARTNERS
- Tuskegee University (Minority institution)
- Bevill State Comm. College
- Lawson State Comm. College
- Heritage Community Center

TECHNICAL AREAS FOR GATE SCHOLARS THESIS / DISSERTATIONS

Lightweight Materials & Manufacturing – Engineered Composites / Castings / Enhanced Crashworthiness
(*Basic science studies leading to Prototype/Application Development & Commercialization*)

Next Generation Carbon Fiber for Automotive &Transportation	Textile grade carbon fiber; reclaimed carbon fiber; wet laid carbon fiber; intermediate forms, effects of sizing; compounded carbon/foams; LFT injection & compression
Next Generation Renewable Materials for Automotive &Transportation	Interface treatment of biocomposites, Bioresins, Moisture uptake and prevention; Processing and blending of natural fibers with synthetic fibers
Advanced Metal Castings	Magnesium and aluminum casting; Austempered steels, Lost foam casting, In-situ X-ray analysis, predictive engineering , pressure assisted casting
Biomechanical studies / Crashworthiness modeling	Injury biomechanics, side impacts-material/body interaction on pelvis; crashworthin--ess modeling; body collision, pedestrian and child car safety studies

INDUSTRY & Other Partnership
- Automotive & Mass Transit Companies
- Economic Development Partnerhship Agency (EDPA)
- Material Suppliers & End-Users
- Alabama Manufacturers
- National Composite Center
- American Chemical Council

NATIONAL / DOE LAB Partnership
- Oak Ridge National Lab (ORNL)
- Pacific Northwest National Lab, (PNNL)
- National Transportation Research Center (NTRC)
- US Department of Agriculture (USDA)

ADVISORY BOARD
- Automotive & Heavy truck reps (Mercedes, Honda, others)
- DOE program managers_
- Material focused industry reps
- Economic Development reps

2013-2014 Milestones

Milestones	Status
Support 3 graduate students/year (two supported by DOE and one cost shared by UAB) with research projects focused on automotive applications	GATE scholars - Danila Kaliberov, Kristin Hardin, Hicham Ghossein, Qiushi Wang, Siddhartha Brahma
Support 4 undergraduates each year in automotive related research	Raymond Solomon, Nicole Mubarak, Eric Wright and John Walker working on GATE
Develop and offer automotive related courses with the potential to impact 20 – 30 students per year	Frontiers of Automotive Materials – 26 students enrolled (Spring 2014)
• Influence at least 30 students per year through hands-on workshops • Undergraduate students (promote graduate studies) • High school students (exposure to automotive area) • Include a focus on minority students (tap into workforce)	DOE GATE workshops on lightweight metal casting, composites manufacturing, materials selection and recycling offered Summer & Fall 2013 and Spring 2014.
Interact with industry and DOE Labs	• Interaction with ORNL CFTF • ~15 industry relationships leveraged
Briefings OEMs	Briefing to MTT team, February 2014

Project Approach to Deployment

What is Project Intended to Accomplish?

- To provide a new generation of engineers and scientists with knowledge and skills in advanced automotive technologies.

Project objectives, including tasks from Statement of Project Objectives

- Train and produce graduates in lightweight automotive materials technologies
- Structure the engineering curricula to produce specialists in the automotive area
- Leverage automotive industry in the State of Alabama
- Expose minority students to advanced technologies early in their career
- Develop innovative virtual classroom capabilities tied to real manufacturing operations
- Integrate synergistic, multi-departmental activities to produce new product and manufacturing technologies for more damage tolerant, cost-effective, and lighter automotive structures.

How project is integrated with other research or deployment projects within the VT Program – Close interactions with DOE Oak Ridge National Laboratory Carbon Fiber Technology Facility (CFTF).

Milestones: GATE scholars, industry and DOE interaction and course offerings are on target

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Project Accomplishments and Progress

and

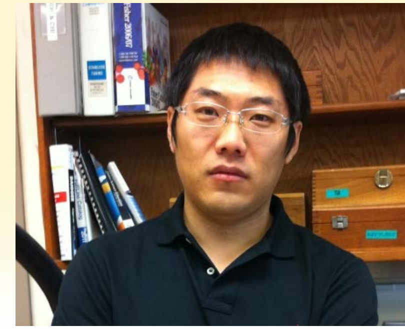
Collaboration and Coordination with Project Partners

Current GATE Scholars

Samuel Jasper,
PhD topic:
Vibration damping

Kristin Hardin
MS topic: Thermoplastic
Recycling compounding

Alejandra Constante
PhD topic: Thermoplastic
Biocomposites



Qiushi Wang
PhD topic: New Test Standards
in Carbon Thermoplastic

Khongor Jamiyanaa
MS: Thermoplastic pultrusion

Danila Kaliberov
PhD topic: LFT & CFTF
joining

William Warriner:
Extrusion-compression
molding

Ahmed Hassen
PhD topic: NDE of long
fiber thermoplastics

Siddhartha Brahma
PhD topic: Carbon thermoplastics

Theresa Bayush, MS (L)
and Melike Onat, PhD (R)
Twin screw compounding
of carbon fiber
thermoplastics

Hicham Ghossein
PhD topic: Wet-laid
Carbon fibers

GATE Directly Funded Students (2013-2014)

GATE – Graduate scholars

	GATE Scholar	Department and Standing	GATE Thesis / Research
1	Melike Dizbay-Onat	Interdisciplinary Engineering, PhD	Carbon footprint reduction and emission absorption by natural fiber composites
2	Danila Kaliberov	Materials Science & Engineering, Pursuing PhD	Threaded long fiber thermoplastic composites
3	Alejandra Constante	Materials Science & Engineering, PhD	Natural fiber composites for automotive applications
4	Khongor Jaamiyana	Materials Science & Engineering, PhD	Modeling of thermoplastic pultrusion for truck frames
5	Hicham Ghossein	Interdisciplinary Engineering, PhD	Nanofiber sizing and carbon fiber integration
6	Kristin Hardin	Materials Science & Engineering, MS	Recycling and compounding
7	Siddhartha Brahma	Materials Science & Engineering, PhD	Wet laid thermoplastics
8	Qiushin Wang	Materials Science & Engineering, PhD	Fiber content measurement in carbon fiber composites
9	Ahmed Arabi Hassen	Materials Science & Engineering, PhD	Nondestructive testing of LFT Composites
10	Theresa Bayush	Materials Science & Engineering, MS	Flax based composites and tractor component fabrication
11	Samuel Jasper	Materials Science & Engineering, PhD	Vibration damping of thermoplastic composites

GATE – Undergraduate scholars pipeline

	GATE Scholar	Department and Standing	GATE Research
1	Nicole Mubarak	Materials Science & Engineering, Junior	Short carbon fiber materials
2	Ranae Wright	Materials Science & Engineering, Pursuing PhD, Junior	Sandwich composites with high damping and energy absorption capabilities
3	Raymond C. Solomon	Mechanical Engineering, Sophomore	Carbon fiber orientation evaluation in long fiber plaques
4	Eric Wright	Materials Science & Engineering, Senior	Contact angle measurements on carbon fiber with different tow sizes and sizing

Accomplishments and Progress: GATE Directly Funded Students (2005-2011)

	GATE SCHOLAR	WHERE PLACED	GATE Thesis / Dissertation
1	Mohammed Shohel	KBR, Houston, (CEE, PhD ‘06)	Resin infusion processing of laminated composites
2	Carol Ochoa	Fenner Belts, Pennsylvania (MSE, PhD ’09)	Finite element analysis and modeling of thermoplastic composites
3	Balaji Venkatachari	CFDRC, Huntsville (ME, PhD’ 09)	Simulation of flow fields in automotive bodies
4	Amol Kant	Owens Corning (CEE, PhD ’09)	Sandwich construction for crashworthiness of automotive applications
5	Lakshya Deka	Whirlpool (MSE, PhD ‘06)	LS-DYNA modeling of of thermoplastic composites
6	Satya Vaddi	Technical Fiber Products (MSE, MS’09)	Fire behavior of thermoplastic composites
7	Felipe Pira	Airbus (MSE, MS’07)	Process Modeling of Thermoplastic Composites
8	Leigh Hudson	Toray Carbon Fibers (MSE, MS’09)	Pultrusion of thermoplastic composite elements
9	Lina Herrera-Estrada	Pursuing PhD at GA Tech (MSE, MS’ 09)	Banana Fiber Composites for automotive applications
10	Danila Kaliberov	Pursuing PhD, UAB (MSE, MS’ 10)	Threaded long fiber thermoplastic composites
11	Michael Magrini	Tyndall Air Force Base (MSE, MS’11)	Impact response of long fiber and laminated thermoplastic composite materials
12	Melike Dizbay-Onat	Interdisciplinary Engineering, Pursuing PhD, UAB, Graduation Dec 2014	Carbon footprint reduction and emission absorpbtion activated carbon composites
13	Aaron Siegel	Jacobs Engineering (MSE, MS’ 12)	Energy absorbing compounded thermoplastic foams for enhanced crashworthiness
14	Peter Barfknecht	MSE, Pursuing PhD (UAB, Dec 2014)	Carbon fiber sizing and liquid molding of reactive thermoplastics
15	Nsiande Mfala	Pursuing PhD, Tuskegee University (MSE, BS’ 2010)	Nanostructured kenaf and banana fiber thermoplastic composites for automotive applications
16	Benjamin Geiger-Willis	MSE. Pursuing PhD 2015	High strain rate impact of thermoplastic composites and foams for crashworthiness

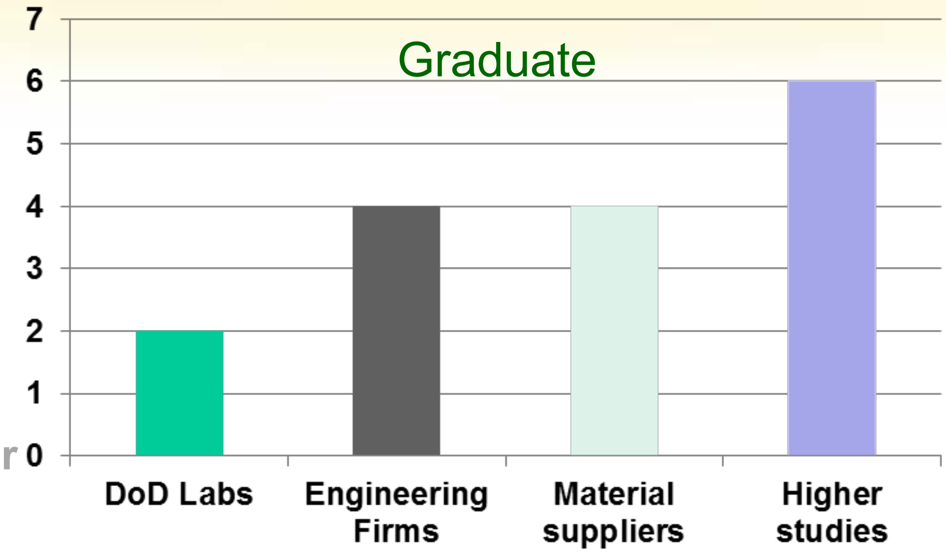
GATE: Undergraduate Student Pipeline

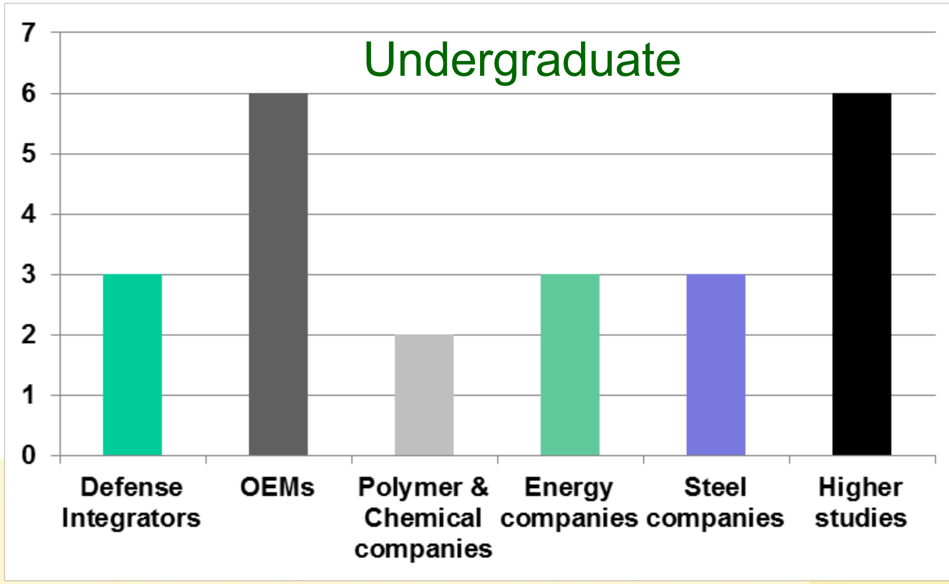
1	Malina Panda	Ford (MSE, BS' 07)	Development of hot-melt impregnated materials
2	Daniel Kaliberov	Pursuing PhD UAB (MSE, Dec 2014)	Vibration testing of long fiber thermoplastic composites
3	Michael Entz	Pursing PhD, NC State University (BS, ME'08)	Impact analysis of laminated composites
5	V. Ameya	Eastman Chemicals (BS, CE'12)	Self reinforced polypropylene studies
6	Hadeel Abdelmajeed	BAE Systems (MSE, BS' 09)	Thermoforming processing of laminated composites
7	Walter Malone	Hanna Steels (MSE, BS'09)	Sandwich panel construction for automotive floor boards
8	Victor Long	Raytheon (MSE, BS'09)	Compression after impact of layered materials
9	David Sexton	Southern Company (MSE, BS'08)	Carbon fiber thermoplastic impregnation
10	Saptarshi Vichare	KBR Houston (BS, 08)	Carbon fiber thermoplastic impregnation
11	Benjamin Rice	Carnegie Mellon (Grad school) (MSE, BS'08)	Compression after impact of E-glass/vinyl ester composites
12	Khongor Jaamiyana	UAB MS 2013/ Intern at Owens Corning	Low velocity impact response of Carbon SMC
13	Alex Johnson	GM (CE'12)	Carbon fiber impregnation and characterization
14	Krishane Suresh	Hyundai, Dec' 12	Long fiber thermoplastics processing
15	Amber Williams	Jefferson County Baccelaureate	Pultruded composites characterization
16	Anshul Bansal	Alabama School of Fine Arts	Fuel cell demo and composite bipolar plates
17	Sueda Baldwin	GE (BS' 08)	Long fiber thermoplastic fiber orientation studies
18	William Warner	Honda of America, Dec'12	Nondestructive evaluation of defects in sandwich composites
19	Theresa Bayush	UAB Pursuing MS; Graduating Summer 13	Nanonstructured banana fibers thermoplastic composites for automotive applications
20	Benjamin Geiger-Willis	UAB Pursuing PhD, December 2015	Split Hopkinson Pressure Bar for high strain rate impact testing of materials
21	Daniel Creamer	Hannah Steel (BS, November 2012)	Lost foam casting
22	J Ranae Wright	Grad School North Carolina (June 2014)	Sustainable bamboo based automotive armor composite
23	Raymond Solomon	Grad School, UAB	High shear energy absorbing materials

GATE fellows to date (2006-present)

27 graduate students (9 MS + 18 PhD)
- **Partially or fully funded by DOE GATE**
- **Research dissertation/thesis focus on GATE topics**
- **Peer-reviewed research publications & papers**

32 undergraduate students (GATE funded)
- **Work study students serve as pipeline for graduate program & GATE fellows**
- **Experiential learning**
- **8 transitioned from undergraduate to become GATE scholars**
- **Participate in poster competitions and undergraduate research forums**





<u>Approximate Demographics</u>
- **30% minority (African-Americans & Hispanic Americans)**
- **40% female engineers**
- **50% Interdisciplinary fields**

GATE students working on Industrial scale facilities - Training

Theresa Bayush (MS candidate) and Melike Onat (PhD candidate) working on natural fiber extrusion

Alejandra Constante (PhD candidate) and Samuel Jasper (PhD candidate) working on composite beams

GATE courses

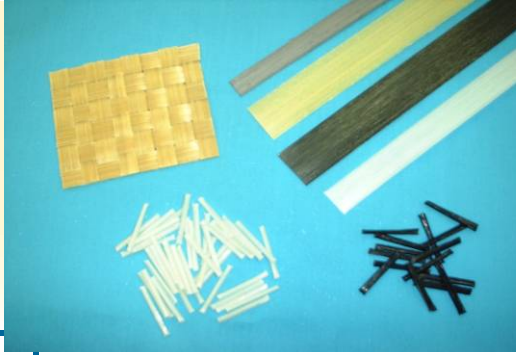
(some newly developed, some based on tailoring content in existing courses)

- **Frontier of Automotive Materials**
- **Composite Design and Manufacturing Technologies for Automotive Applications**
-
- Process Modeling and Simulation for Lightweight Materials
- Optimized Lightweight Material Designs for Prevention of Crash-Related Injuries
-
- Composites Manufacturing
- Advanced Composite Mechanics
- Nano materials for Automotive Applications.
- Process Quality Engineering
- Nondestructive Testing & Evaluation

- Carbon Fiber Technologies for Automotive and Truck
- Sustainable/Renewable Materials and Processing Technologies for Automotive
- Predictive Engineering – Integrated Process Modeling and Design in Composites & Castings
- Materials by Design for Heavy Trucks and Mass Transit
- Materials and Design for Fuel Cell and Hybrid Vehicles
- Modeling and Simulation for Crashworthiness

A GATE scholar takes at least 6 courses of the above 14. The GATE certificate option will be make available to the industry participants as well.

Materials Forms for Advanced Composites Manufacturing



Thermoplastic Matrix Composites

Continuous fiber reinforced thermoplastics

- **Unidirectional tape**
- **Woven prepreg**
- **Other forms (braided prepreg, etc)**

Discontinuous fiber reinforced thermoplastics

- **Long fiber reinforced thermoplastics (LFT)**
- **Short fiber filled thermoplastics**

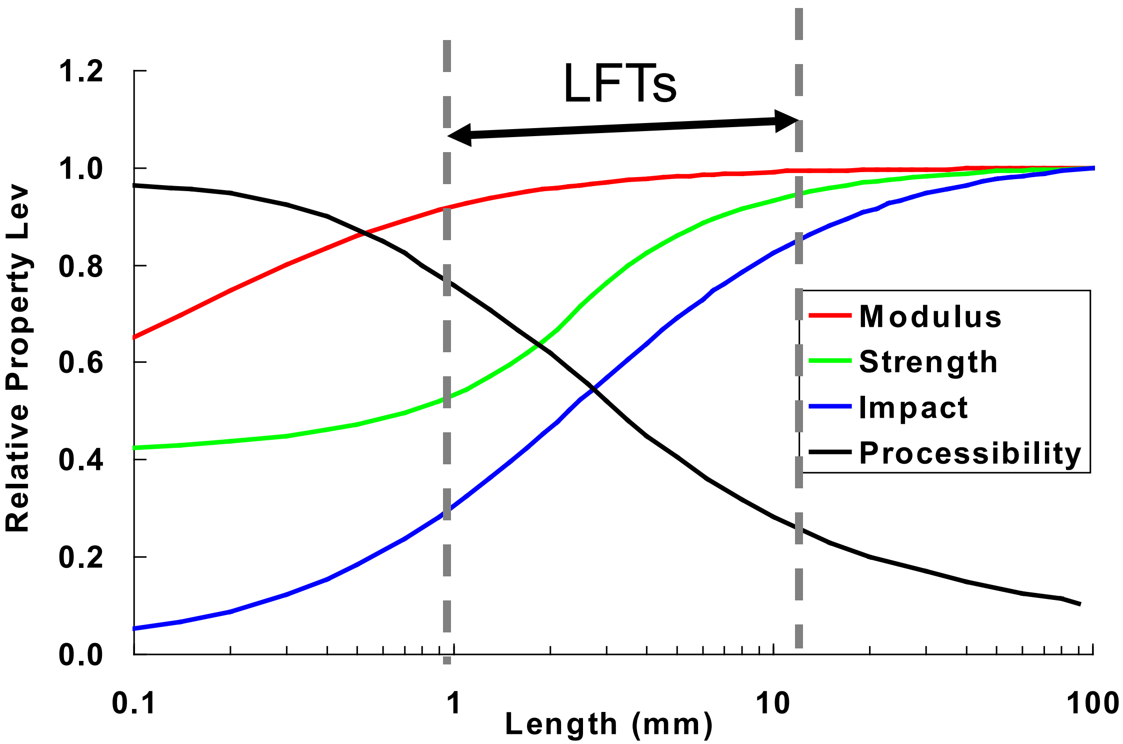
FORMING AND FINISHING OPERATIONS

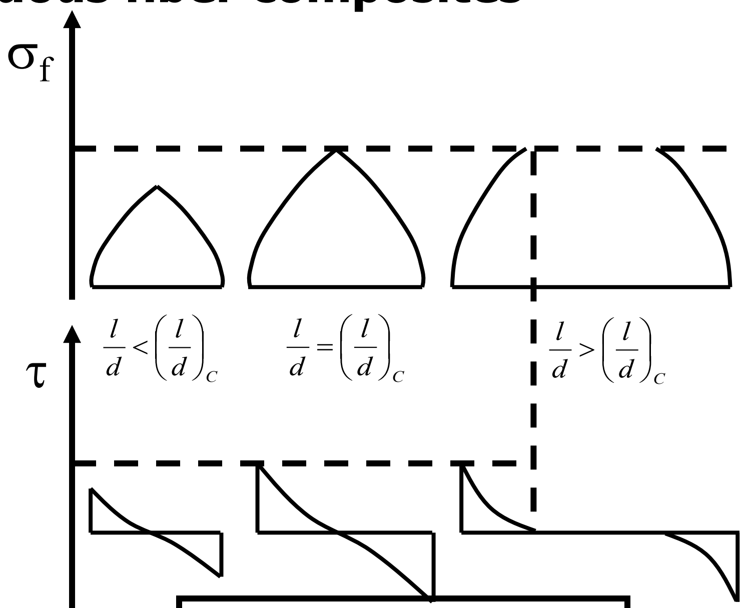
(FIBER INJECTION MOLDING, EXTRUSION, COMPRESSION MOLDING, PULTRUSION, DIAPHRAGM FORMING, THERMOFORMING, ETC...)

END PRODUCT

Long Fiber Thermoplastics (LFT)

Superior mechanical properties in comparison to short fiber composites (higher modulus, higher impact properties, higher tensile strength); elastic properties ~70-90% that of continuous fiber composites





Critical length to diameter ratio:

$$\left(\frac{l}{d}\right)_c = \frac{\sigma_{max}}{2\tau}$$

Source: J. Thomason and M.A. Vlug

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Collaboration with ORNL CFTF

UAB Request of CFTF Inventory Start of Week 10-7-2013							
Fiber Type	Tubes (kg)	OPF Loose (kg)	OPF Tubes (kg)	Loose in Box (kg)	SFF Tubes (kg)	SFF Dry Loose (kg)	SFF Wet Loose (kg)
Blue Star 12K	20						
Blue Star 24K	30	5	10		10		5
Blue Star 48K	30						
Blue Star 12K, 24K, 48K					20		
Kaltex 1.2		10				20	
Kaltex 1.5		10		20		20	5
Totals	80	**25**		**20**	**30**	**40**	**10**

Key:

OPF - Oxidized PAN fiber:	Fiber collected after oxidation steps before carbonization steps.
SFF - Short fiber feed Tubes:	Short fiber feed is the term industry uses when for various reasons, a tube (c
SFF Dry Loose:	fibers) are not suitable for continuous fiber applications but are perfectly go
SFF Wet Loose:	and/or milled applications.

Timeline

- UAB GATE team visited ORNL & CFTF – October 8th, 2013
- Several carbon fibers from CFTF inventory were identified as candidates for downstream composites work by GATE students
- Proposal/request for material was made to CFTF/DOE HQ approval
- Request was approved and material was received by UAB in early Dec 2013

DOWNSTREAM PROCESSING OF ORNL CARBON FIBER

- Hot-melt impregnation of carbon fiber/thermoplastic tapes
- Extrusion-compression molding of carbon/thermoplastics
- Wet-laid processing of carbon fiber/thermoplastic fiber mats
- Dry winding – infusion
- Carbon fiber mats film stacked thermoplastic films

Courtesy: Lee McGetrick, ORNL CFTF

Processing approaches with ORNL Carbon Fibers

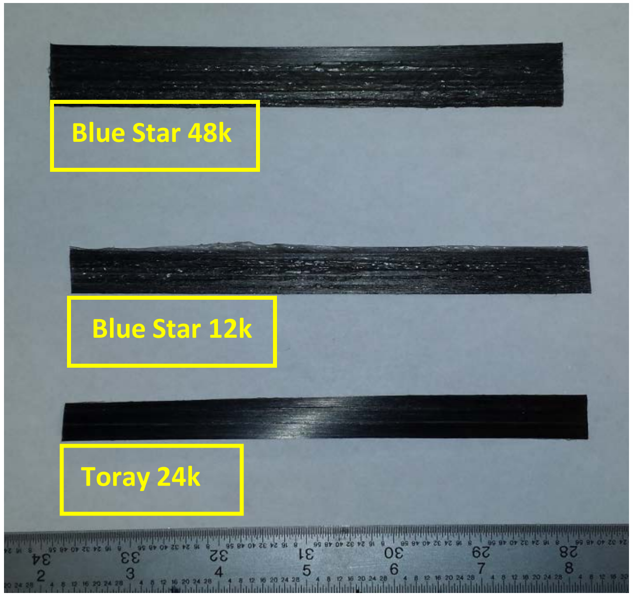
Processing of ORNL fibers

- Hot melt impregnated carbon fiber thermoplastic tapes
- Twin screw direct compounding of carbon fiber – thermoplastic tapes
- Wet-laid creation of ‘carbon only’ mats and ‘carbon-thermoplastic’ mats
- Film stack impregnation of carbon fiber mats
- Dry filament winding of carbon fiber spools

Downstream manufacturing options

- **Extrusion-compression molding (LFT or flakes)**
- **Thermoplastic pultrusion**
- **Compression molding**
- **VARTM (thermosets)**

Hot-melt impregnation of ORNL carbon fiber 12 k, 24 k and 48k into tapes and extrusion-compression molded product

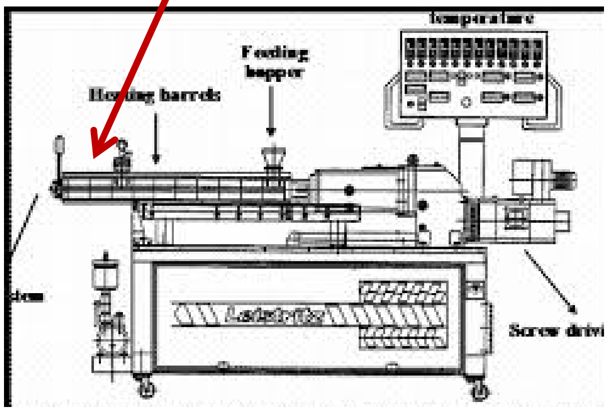


Samples (ORNL)	Carbon Fiber Content
Carbon/PP 12k	8.19%
Carbon/MAPP12k	8.74%
Carbon/PP 48K	19.43%

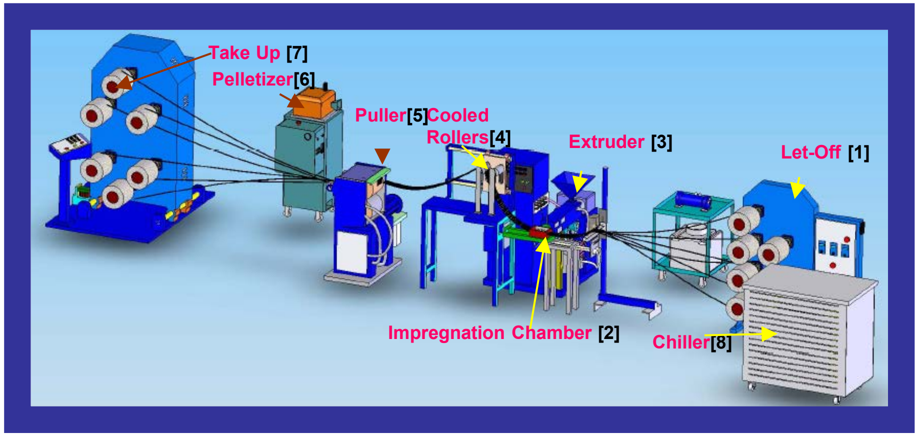
Twin Screw versus Hot Melt Impregnation

Twin screw based carbon/PP tapes

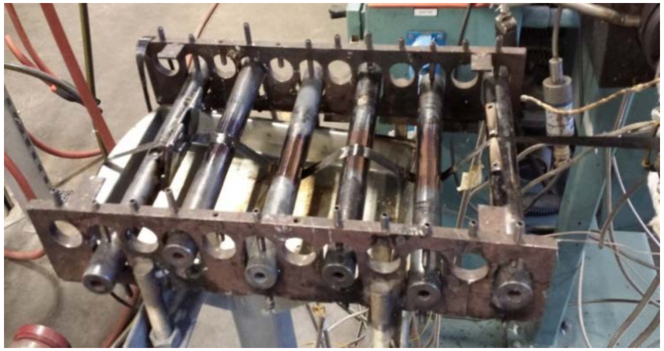
Carbon fiber feed



Hot-melt impregnated carbon/PP tapes



Type	W_f%
T12 TS	6.17%
B12 TS	11.77%
B24 TS	14.11%
B48 TS	17.90%
B12 HM	8.19%
B48 HM	19.43%



Extrusion-compression molding of hot-melt impregnated and twin screw compounded tape-flakes. All test plates molded this way.

Carbon/PP: Effect of Processing via Twin Screw compounding versus Hot Melt Impregnation

Assumptions	Value
Fiber length	3 mm
Fiber Diameter	10 µm
Fiber Modulus	35 Msi
Resin Modulus	0.175 Msi

$$E_{random} = \frac{3}{8}E_{11} + \frac{5}{8}E_{22}$$

$$E_{11} = \left(\frac{1+2\left(\frac{l_f}{d_f}\right)\eta_L v_f}{1-\eta_L v_f}\right)E_m$$

$$E_{22} = \left(\frac{1+2\eta_{Tv_f}}{1-\eta_{Tv_f}}\right)E_m$$

Type	Wf%
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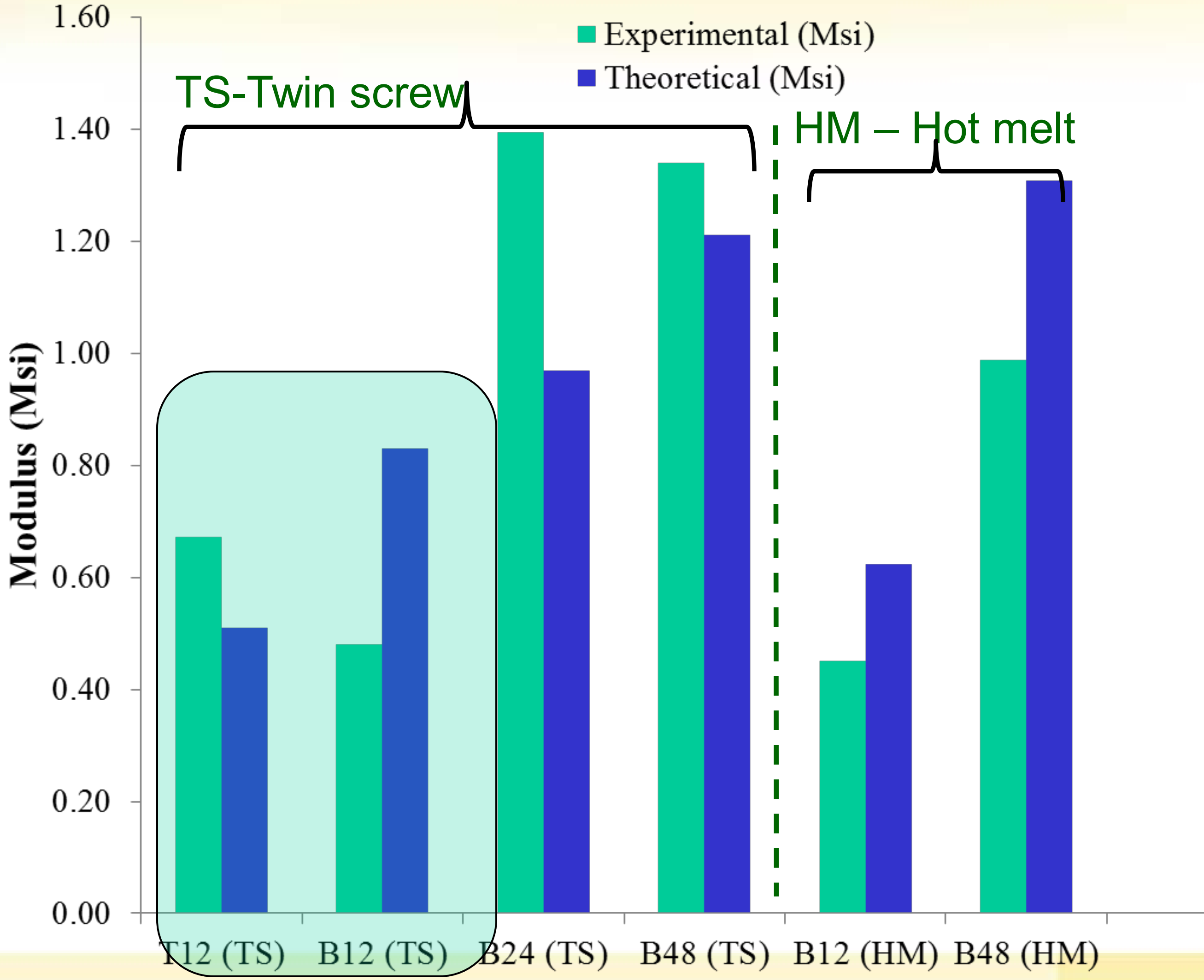
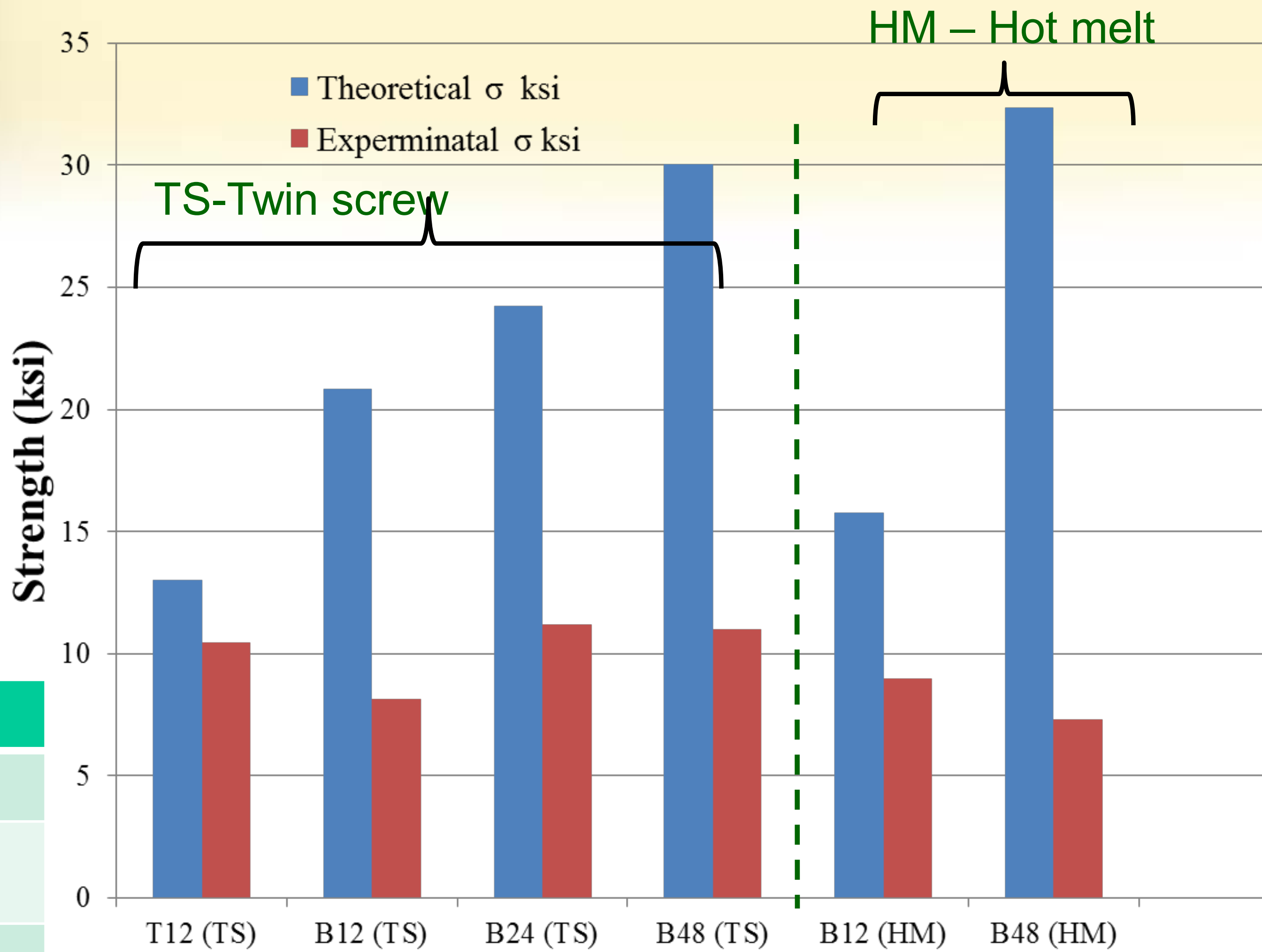


Carbon/PP: Effect of Processing via Twin Screw compounding versus Hot Melt Impregnation

Criteria	Value
Fiber length	3 mm
Fiber Diameter	10 µm
Fiber Strength	700 ksi
Resin Strength(PP)	4.8 ksi

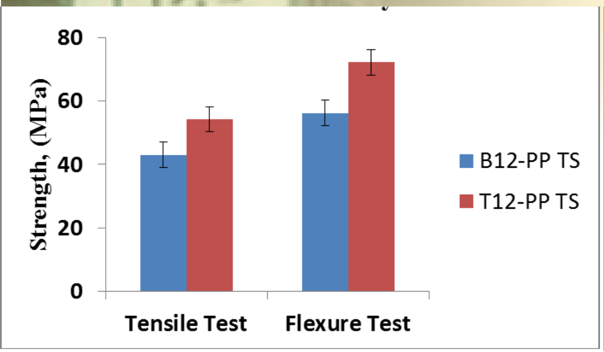


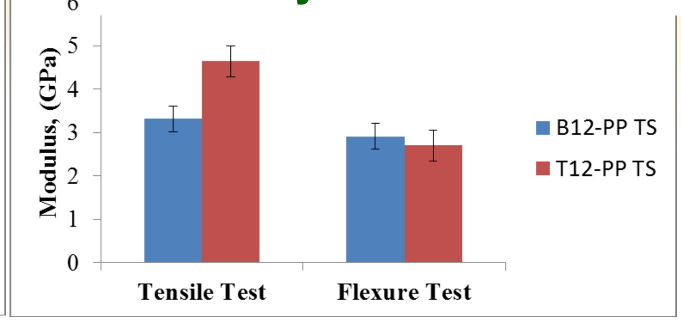
$$\sigma_{random} = \tau_i \frac{l_f}{d_f} v_f + \sigma_m (1 - v_f)$$

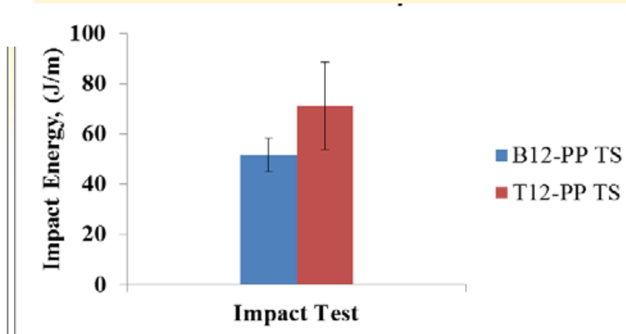
$$\tau_i = \frac{3 d_f \sigma_f}{8 l_f}$$

Tensile, Flexure and Impact Response

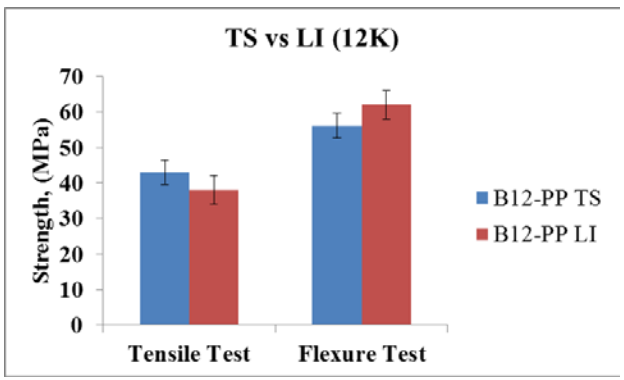
12k- Toray versus Bluestar

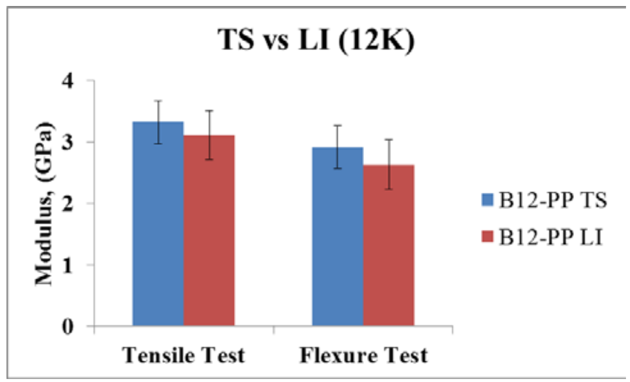


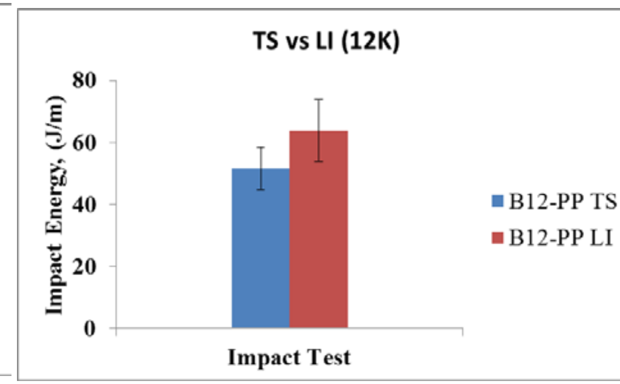




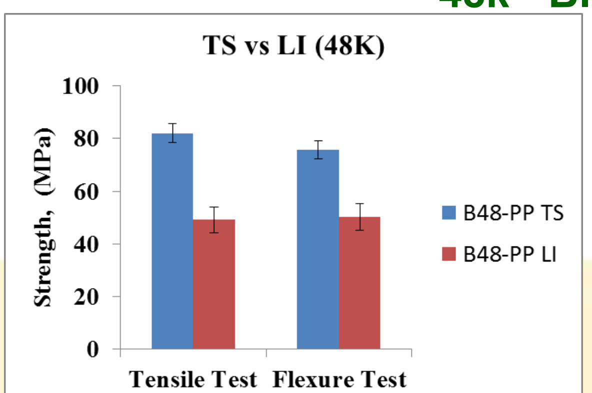
12k - Bluestar Twin Screw vs Hot Melt Line Impregnated

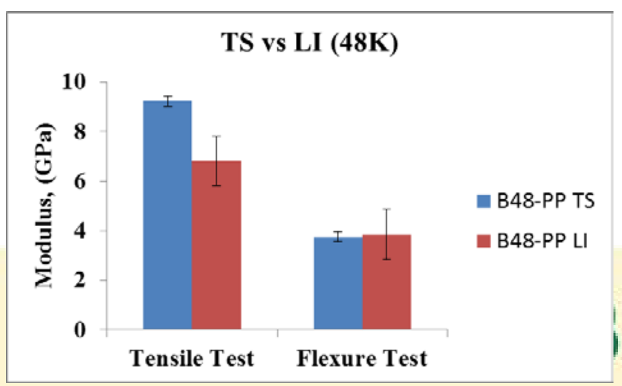


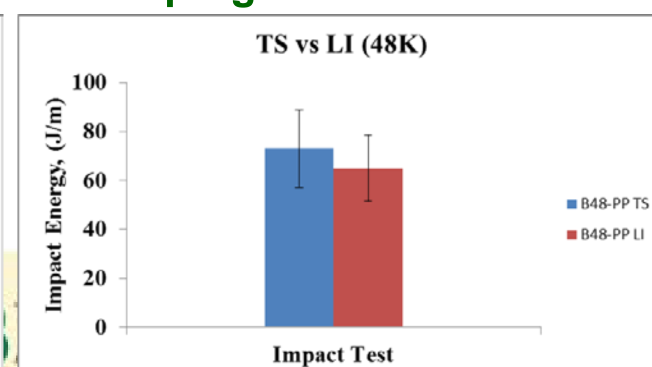




48k - Bluestar Twin Screw vs Hot Melt Line Impregnated



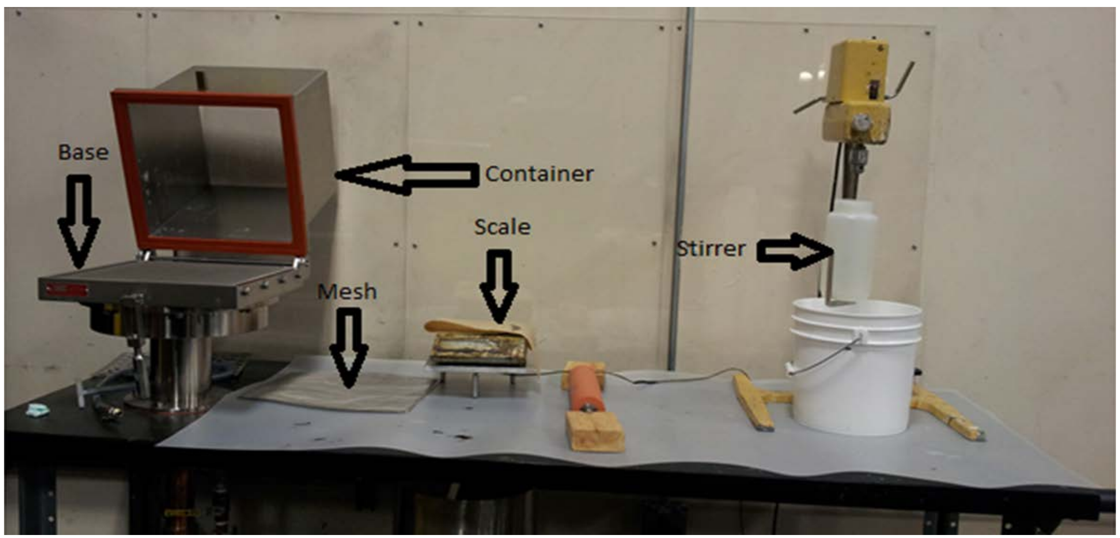




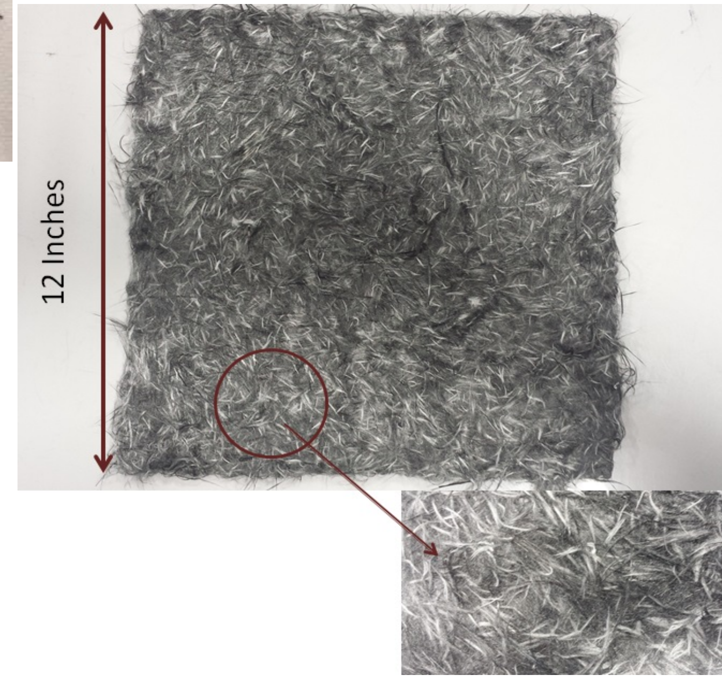
Wet Laid Bluestar Carbon Fiber Thermoplastic Fiber mats (PP, PA6, PPS)

PPS fiber

B48k tow carbon fiber

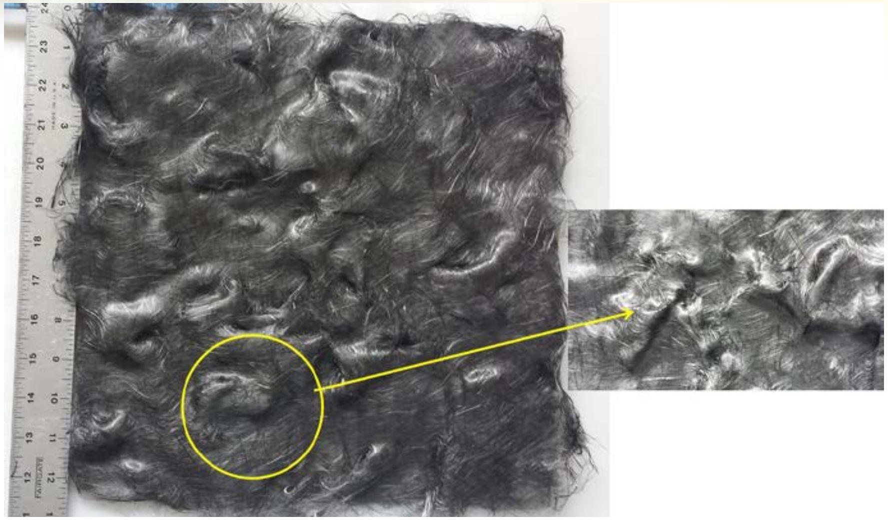


Wet laid set up

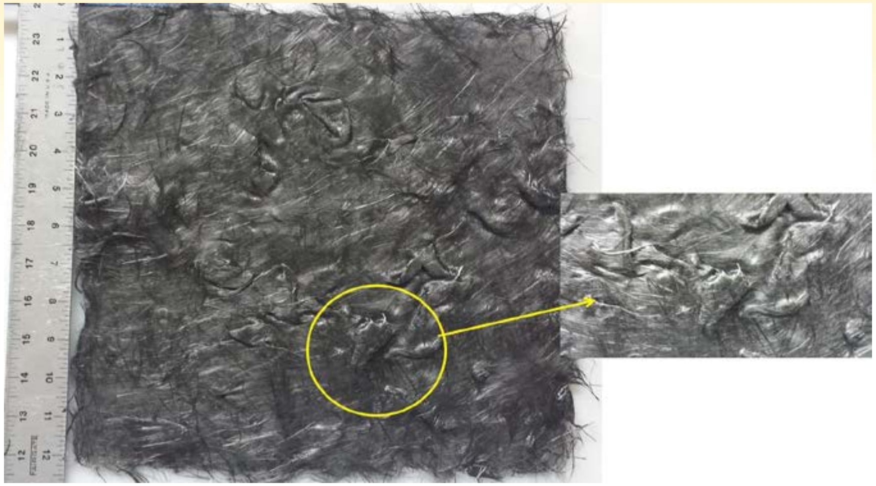


40 wt% carbon/PPS
1” length carbon fiber

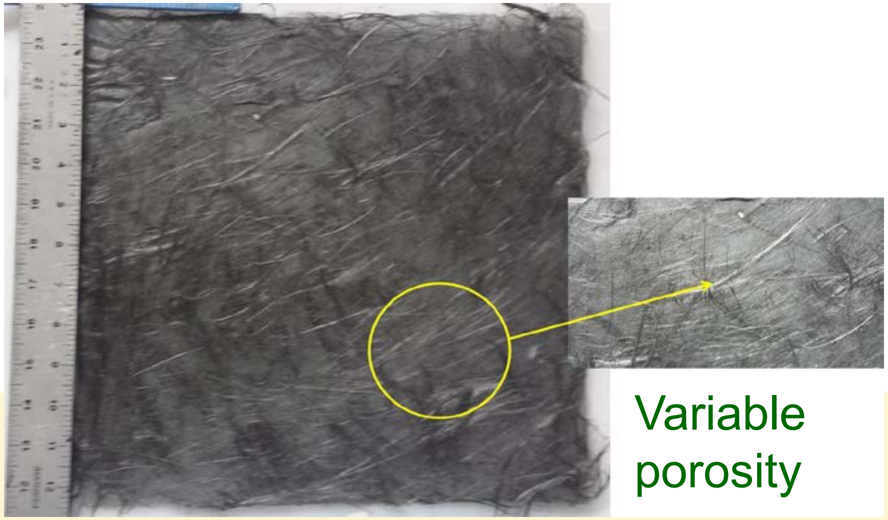
Wet Laid Thermoplastic Mat Process Optimization



Log defects



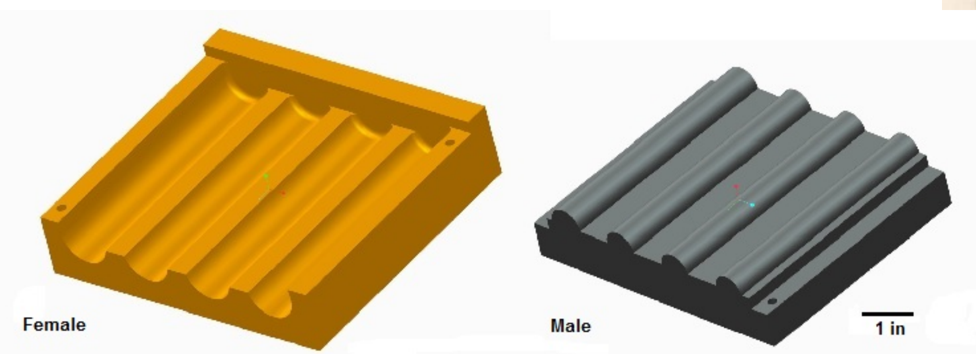
Clump defects

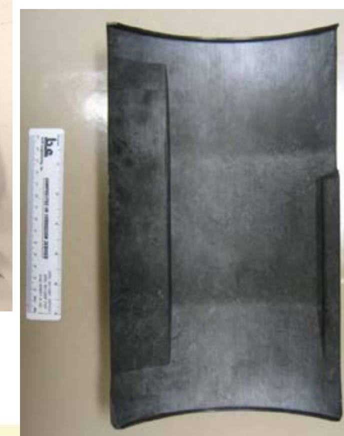


Variable porosity

Compression molded panel

Shapes & Draw features – Product intent– flats, V-ribs, ½ sine, trapezoids made from wet-laid ORNL carbon fiber/nylon fiber mats

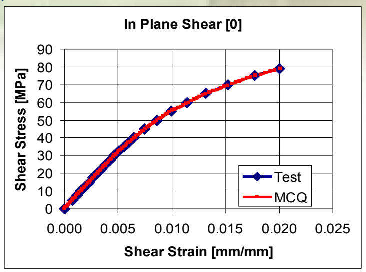




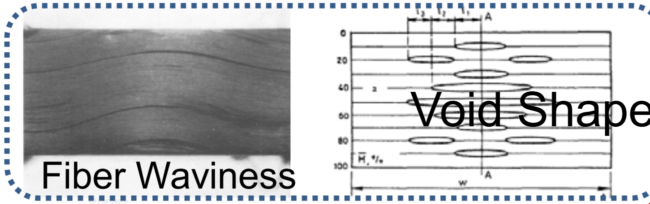
MCQ Composites: Modeling of Discontinuous Fibers

Input

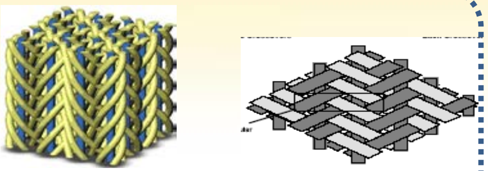
Material Non Linearity



Manufacturing Defects, As-Built



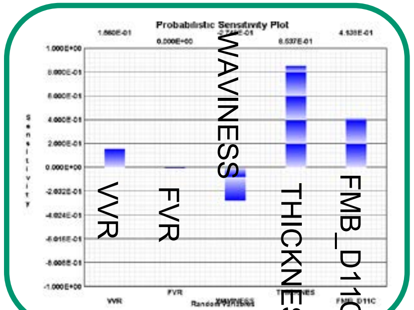
Fiber Architecture



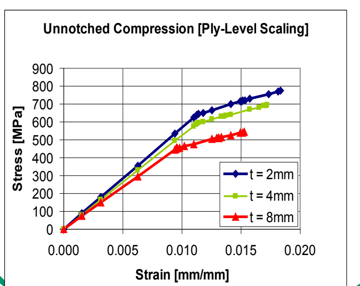
MCQ Composites

Predicts Laminate Properties, Reduce Coupon Testing & Accounts for Scatter

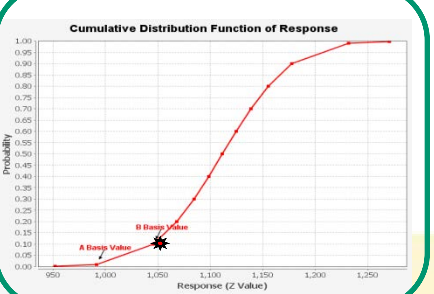
Probabilistic Sensitivity



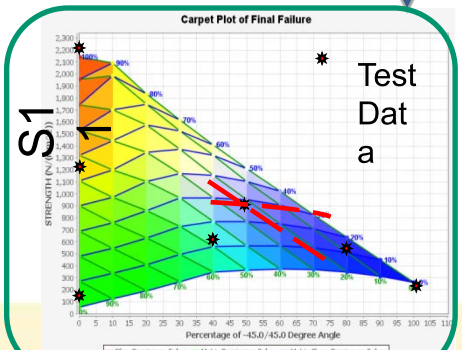
Thickness Effect



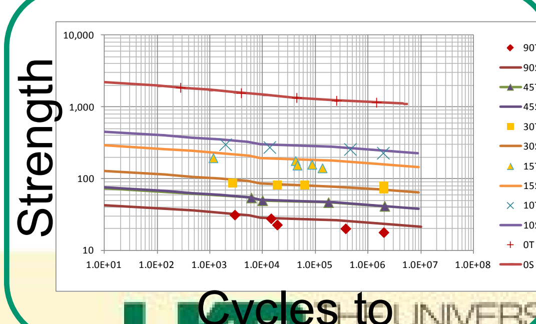
A- & B-Basis Allowables



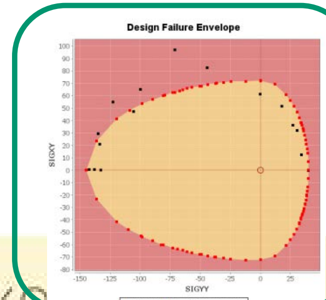
Parametric Carpet Plots



Fatigue Life



Design Failure Envelope



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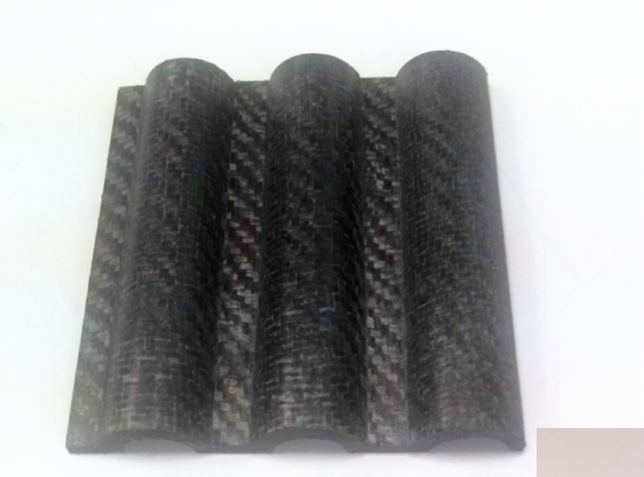
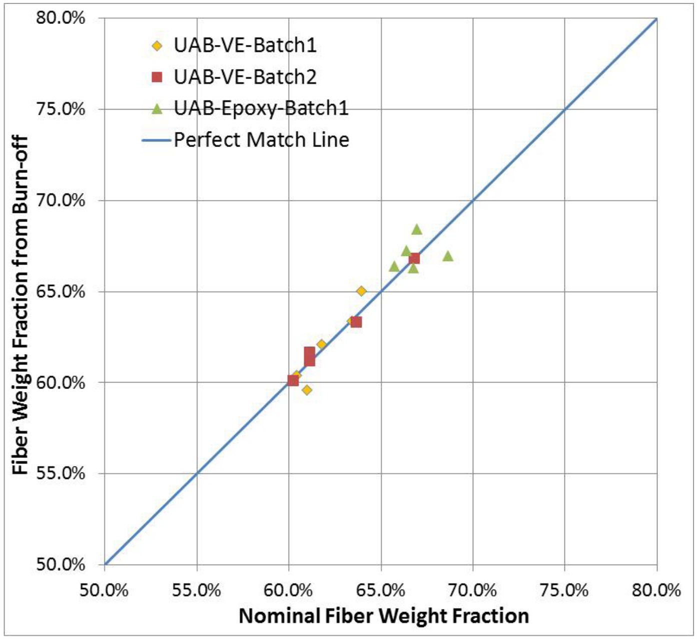
Carbon Fiber
Commingled Fibers
C/PEEK, C/PPS
C/Nylon



New Method for Carbon Fiber Content Determination in Carbon Fiber composites

- Carbon fiber content plays a critical role in determining the properties of composites.
- ASTM D3171 - Standard Test Methods for Constituent Content of Composite Materials is currently used for measuring carbon fiber content.
- A new burn-off method (different from the procedures specified in ASTM D3171) is developed that accurately measures the carbon fiber content (being reviewed by ASTM sub-committee).
- Non-hazardous and does not require long digestion time



Comparison between nominal and measured carbon fiber content from burn-off method

Sample	M total (g)	M carbon fiber(g)	M residual (g)	W% nominal	W% (burn-off result)	Deviation
1	2.142	1.43	1.462	66.76%	66.28%	-0.48%
2	1.971	1.32	1.385	66.97%	68.42%	1.45%
3	1.734	1.19	1.195	68.63%	66.98%	-1.65%
4	2.145	1.41	1.466	65.73%	66.38%	0.65%
5	1.747	1.16	1.208	66.40%	67.23%	0.83%
Neat Epoxy	5.367	--	0.314	--	--	--

Composite sample before burn-off

Residue from composite sample after burn-off

Residue from neat resin after burn-off

SHELL ECO-MARATHON FUEL EFFICIENT VEHICLE

Brandon Caterinichia, John Herring, Nick Iannuzzi, Shaylin Gehring

Mentor – Hessam Taherian

Problem Statement

A prototype car was designed and fabricated for the 2014 Shell Eco-Marathon Challenge with the goal of designing the most capable fuel efficient car. The team - 4 mechanical engineering students with the assistance of an additional five volunteers to complete this year's design with new ideas and theories.

Design Constraints

Dimensions

Height < 100 cm   Weight < 140 kg

Width <130 cm   Wheelbase > 100 cm

Vehicle Track > 50

Miscellaneous

Rollbar > 5 cm Above Driver's Head

Rollbar Capable of Withstanding 700 N

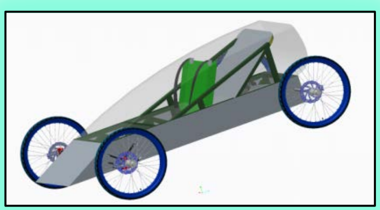
Vehicle Must Have a Solid Floor

Wheels, Steering, Braking

8 Meter Turn Radius

2 Separate Braking Systems

Inspection Incline of 20 Degrees



CAD drawings were designed using Creo Parametric 2.0.

Engine Requirements:

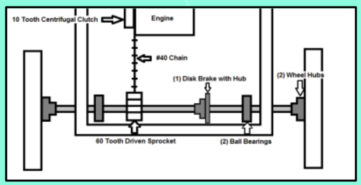
The estimated car and driver weight is estimated to be between 250 - 280 lbs. The objective is to reach 35 mph for coasting. The max speed can be reached within 10 sec at 1.56 $\frac{m}{s^2}$ and requires 1.86 HP.

$$horsepower = weight \times \left(\frac{velocity}{234}\right)^3$$

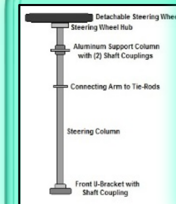
Engine Specifications:

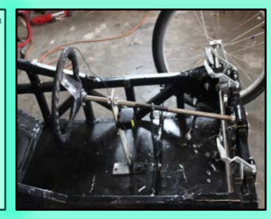
The Honda GXH50 engine generates 2.1 HP and delivers 2.1 ft·lb at 4500 rpm.

Transmission



Steering





The transmission has a 6:1 gear ratio with 26 inch wheels to coast as long and far as possible. The larger the wheel size, the farther the vehicle can coast without using unnecessary fuel.

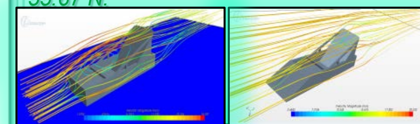
Rolling Resistance

The average rolling resistance constant, c, is 0.002. For an estimated weight of 250 - 280 lbs, a rolling resistance of only 2.23 N is needed due to

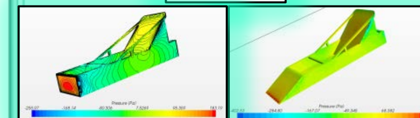
$F_r = cW$ where W is the weight.

CFD Analysis

Star-CCM+ was used for aerodynamic analysis over the frame. By adding a 25 degree nose to the front of the body, the drag coefficient was lowered from 1.204 to 0.9324 and the drag force from 71.92 to 55.67 N.

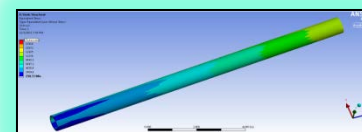


$$C_D = \frac{F_D}{0.5\rho_\infty V_\infty{}^2 A}$$



Finite Element Analysis

An FEM analysis of the rear driven axle was simulated and the maximum stress was caused by the chain at 20,024 psi.

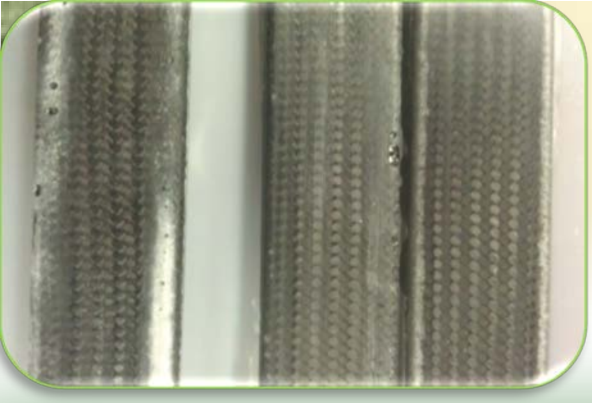


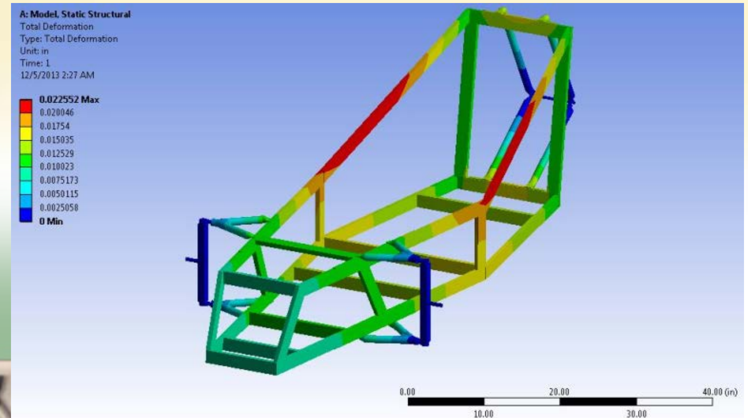
Electrathon

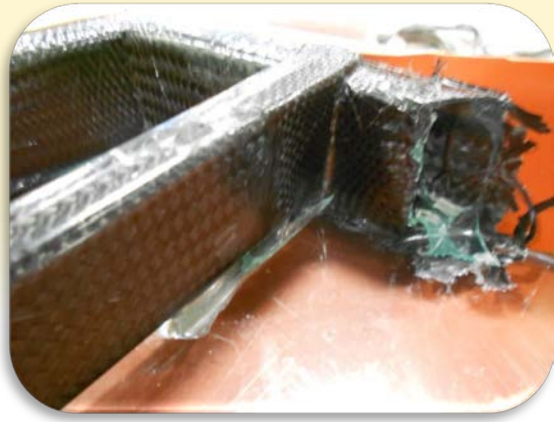
M. Catherine Clark , Amie Eder
Chris Graves, J. Ranae Wright

Barber Motorsports,
Leeds, Alabama
UAB Team - 2nd place

Electrathon Team







Weight of the frame: 24lbs

GATE - Industry Leverage

GATE
GATEWAY TO THE FUTURE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

MIT RCF
REENGINEERED CARBON FIBER

eSpin

PPG

NSF

UAB THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

OWENS CORNING

ZOLTEK

Composites Innovation Centre

TORAY

SIOUX Manufacturing Corporation

HONDA
Honda of America Mfg., Inc.

DAIMLER
Daimler Trucks North America

NABI INC.

FTA U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL TRANSIT ADMINISTRATION

HYUNDAI

National Composites Center

MacDon

Great Dane

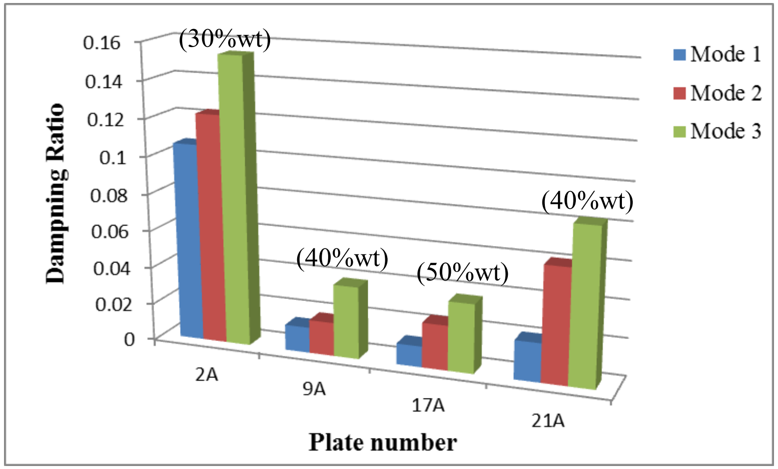
polystrand

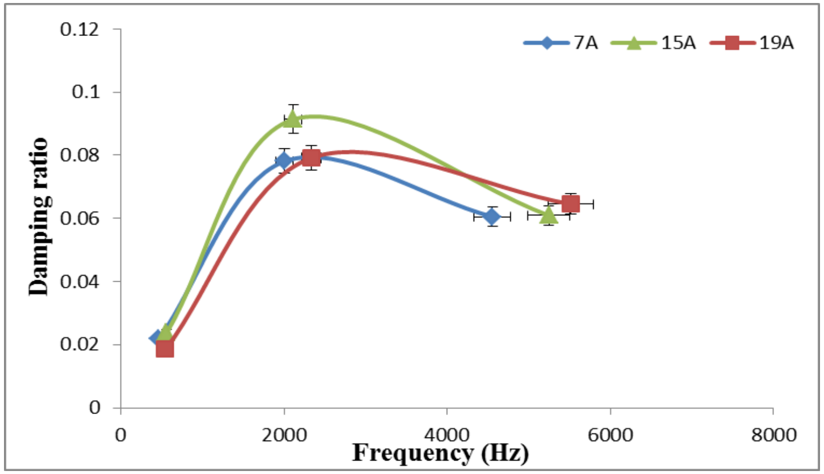
Laurel BioComposite, LLC
Clean. Green. Renewable

GATE Collaboration with MIT-RCF

MIT-LLC Project Planning and Execution Document (PPED) for GATE Program at UAB

- **Project Name:** RCF-LFT: effects of fiber length, resin viscosity, and mixing
- **Project Partner:** Materials Innovation Technologies LLC, Fletcher, NC
- **Project Monitor:** Dr. Mark Janney
- **Brief Project Description:** Define the roles played by fiber length, resin viscosity, and methods of mixing in determining the mechanical properties of compression molded long fiber thermoplastic (LFT) composites made from recycled carbon fiber. Properties can be directly compared with RCF-PET Co-DEP properties form MIT-LLC DOE III project.





MITRCF
REENGINEERED CARBON FIBER

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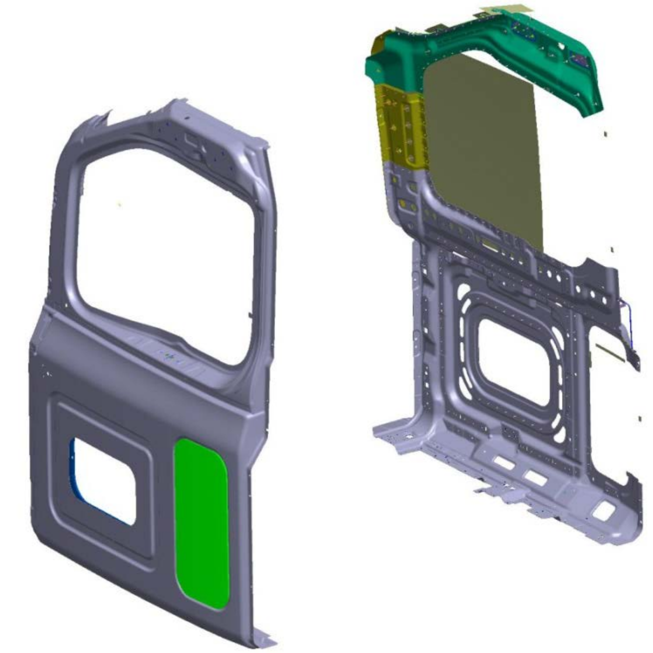
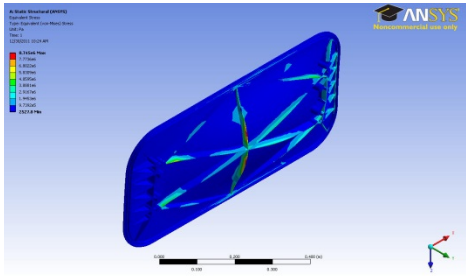
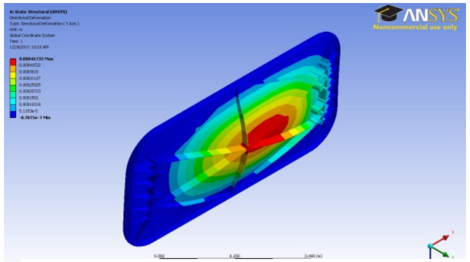
Composite Door for Truck



LFT Extrusion-compression molded part–
Material selection – Weight & performance optimization

Design Variable		Material	Max deflection (mm)	Mass (kg)	Weight savings
Aluminum design (baseline)		Aluminum	0.23	2.5	--
Panel (mm)	Rib (mm)	Composite Design			
3	2	40 wt% glass-Nylon66	0.35	1.78	28.7%
4	2		0.33	2.19	12.5%
4	3		0.30	2.26	9.7%
3	2	40 wt% glass-Nylon66 + 40wt%carbon-Nylon66 hybrid	**0.23**	1.72	**31.1%**
4	2		**0.21**	2.11	**15.5%**
4	3		**0.19**	2.18	**12.8%**

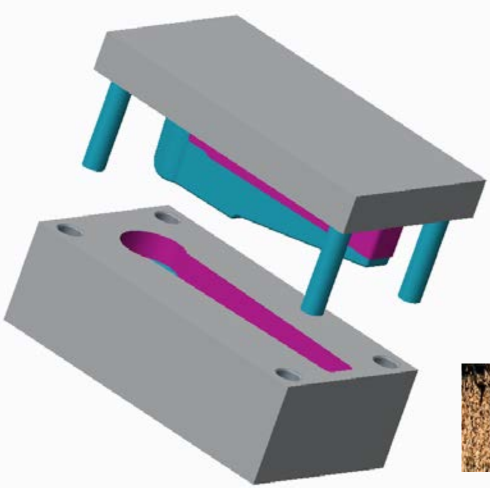




- Maximum stress: 8.7 MPa
- Max deflection: 0.47 mm
- Mass: 1.84 kg
- Weight saving: 26.4%

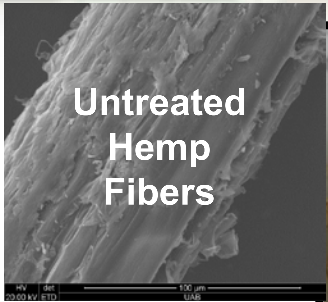
MacDon – Duct Screen Cleaner

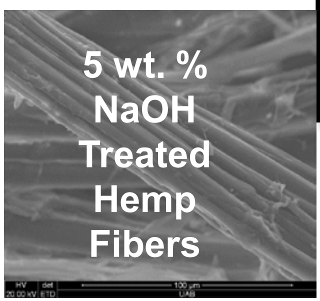
- Develop compounding and processing parameters for achieving maximum fiber aspect ratio of hemp fiber.
- Investigate fiber treatments and coupling agents for enhanced fiber matrix interface
- Evaluate PP/hemp fiber composite for manufacture of duct screen cleaner for MacDon tractor application; mechanical testing, thermal characterization, UV stability, hydrothermal aging.
- Redesign duct screen cleaner for extrusion-compression molding (ECM).
- Design tooling for proto-typing of part / Prototype and test.
- Volume 650 parts per year.

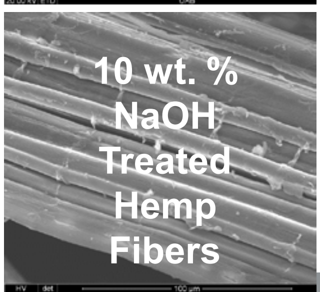


Hemp Fiber/PP Composites

Hemp Fibers







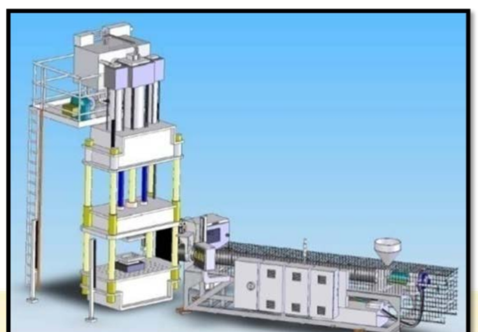
+

Polypropylene

Twin Screw Extruder

Die redesigned for minimum shear producing compounded Tape Form

Chopped tape



ECM Cell

6"x6" ECM plates

Recycled High Strength Materials and Processes for Ground Transportation

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GATE Collaboration with Community Colleges and Partners

- Roane Community College, Oak Ridge – with Dave Warren, ORNL – Composites Accelerator Program; Fall 2013

- Peninsula Community College, Seattle – Recycling of Composites; April 22, 2014

- On-line workshops for industry
  - Thermal Analysis & Rheology of Polymers; May 8th 2014
  - Design & Modeling of Composites, July 23, 2014

GATE Deliverables Summary 2013- 2014

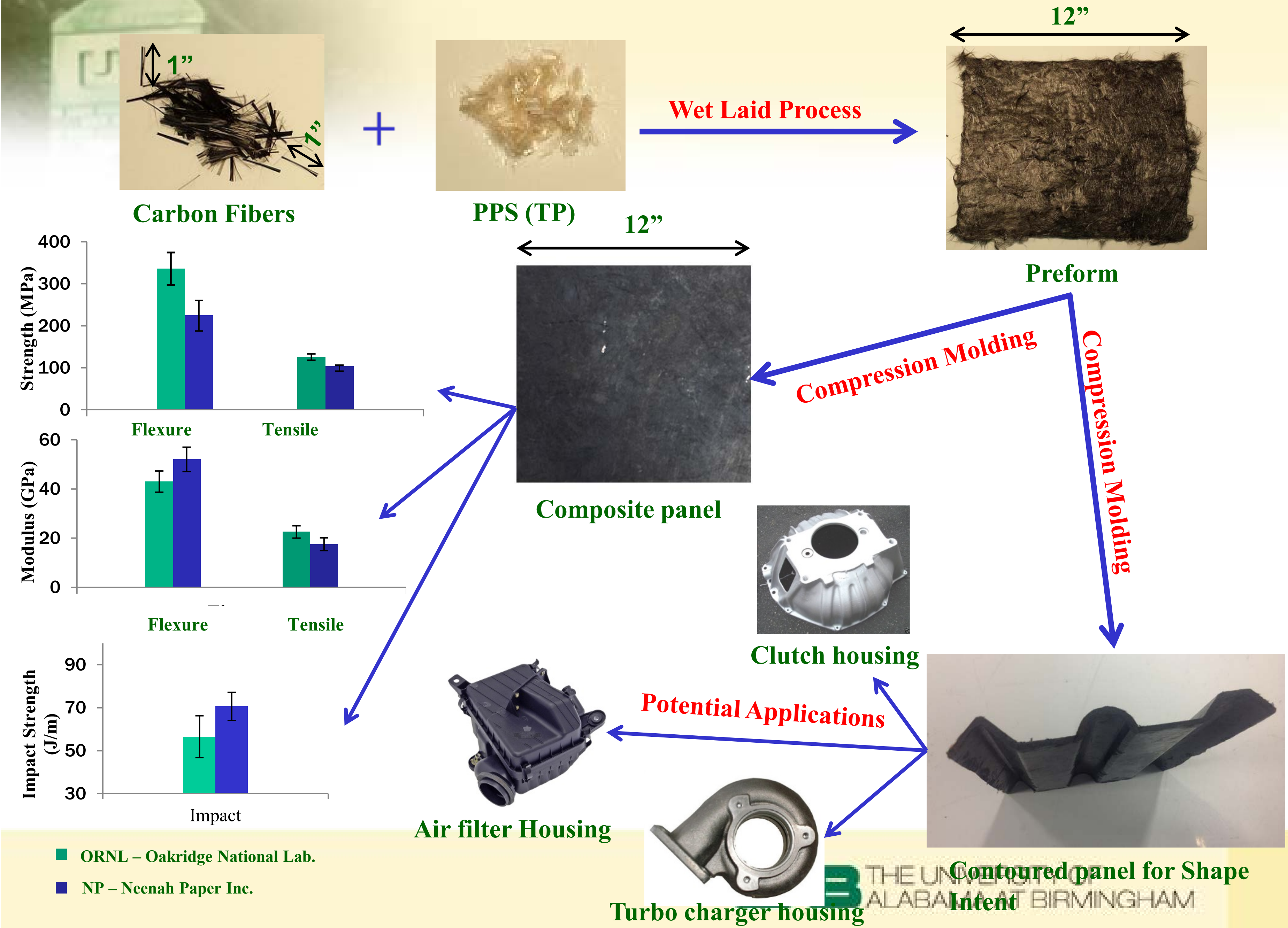
- ✓ Support 3 graduate students/year - 5 *graduate students have been supported to date by GATE funds (2013-2014)*
- ✓ Support 4 undergraduates each year – 6 *undergraduates have been supported (2013-2014)*
- ✓ Develop and offer two new automotive related courses per year to impact 20 to 30 students per year – *3 GATE courses were offered in 2013-2014*
- ✓ Influence at least 30 students per year through hands-on workshops – *3 workshops have been offered in 2013-2014 (95 students)*
- ✓ Interact with industry through Advisory Board meetings, industry tours, collaboration through the virtual classroom, and interaction on research projects (including SBIRs and STTRs) – *all aspects are being addressed consistently and increasing industry collaboration with the UAB GATE*

Technical Summary

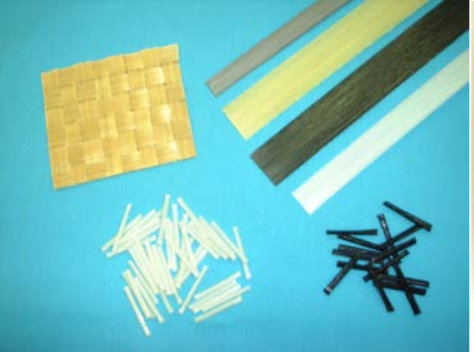
- The work with ORNL carbon fiber is leading to new knowledge about the down stream processing into thermoplastic and thermoset carbon fiber composites
- Designers and end-users will benefit from the data base and material-manufacturing knowledge
- Tooling is available at the UAB Center for mass transit components – prototypes and product intent parts can be readily scaled up with ORNL and related fibers
- Selective insertion of cost-effective, lighter, high performing, mass produced composite parts for automotive and transportation.
- Next generation work-force development and trained engineers for DOE, OEMs and related industries
- Applications developed ready for commercialization.

Technical Backup Slides

Wet Laid Thermoplastic Process

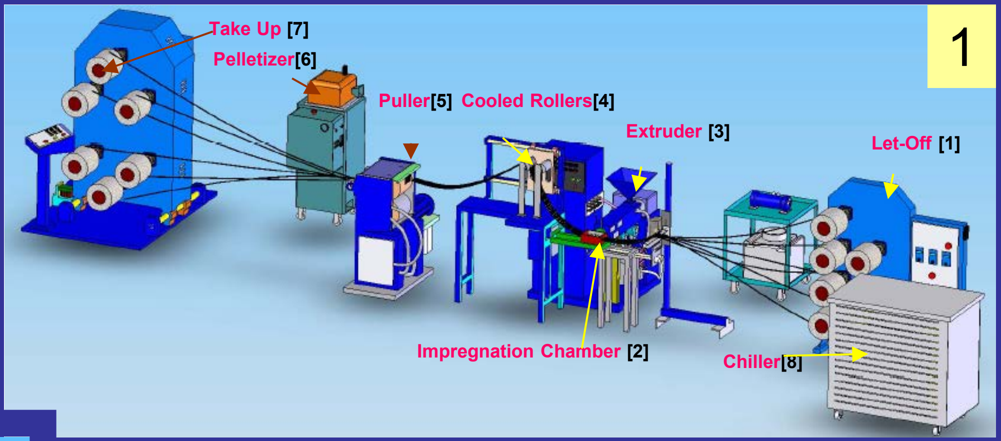


Compounding Micro-Sphere Pellets

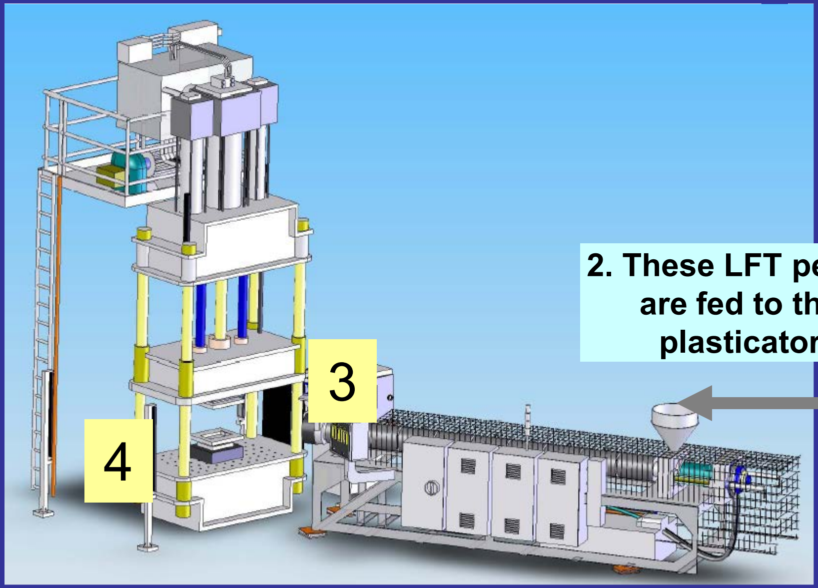


Long Fiber Thermoplastic (LFT) Composites Processing Technology

3. The polymer in the LFT pellets melts to produce a molten fiber-filled charge that is then compression molded.



1. Hot-Melt Impregnation: Dry fibers are impregnated with extruded thermoplastic polymer in a die. The rod material is chopped into long fiber pellets (of 0.5” to 1” fiber lengths)



2. These LFT pellets are fed to the plasticator

Representative molded part

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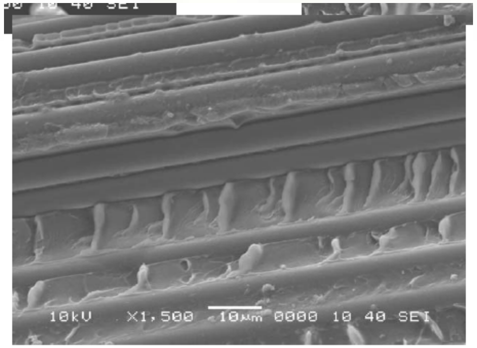
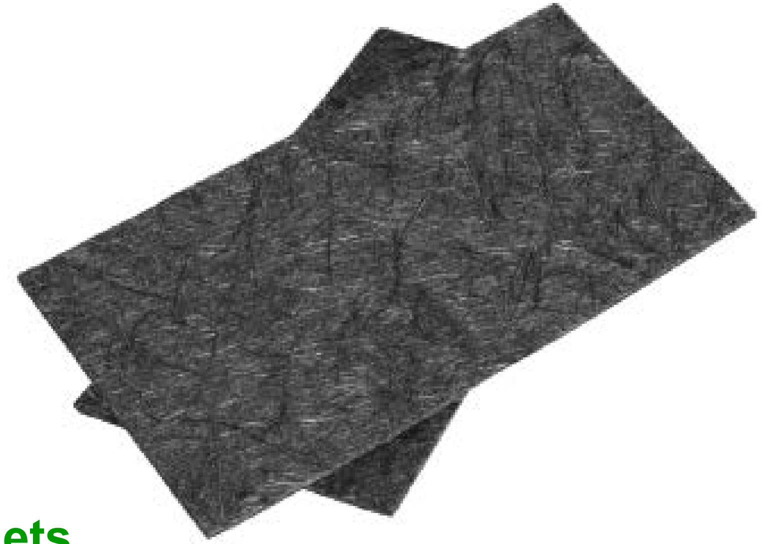
Representative Material Forms

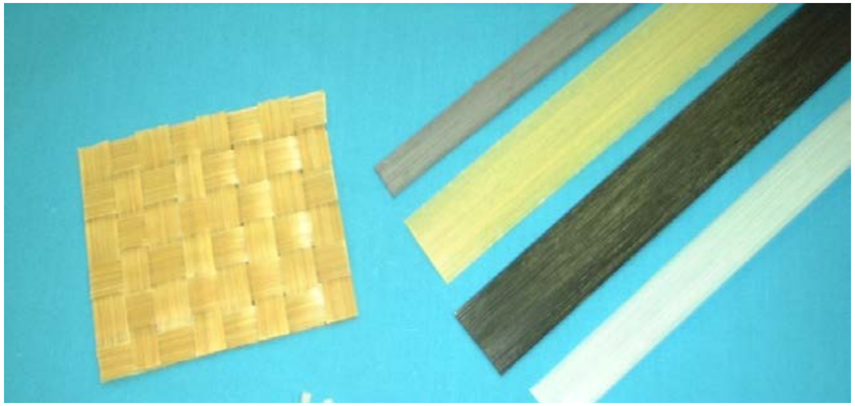


Intimate wet-out

Simple blends, hot-melt pellets

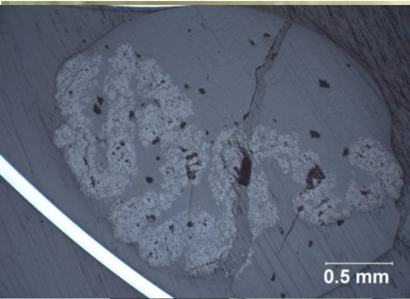


Wet-laid or roll bonded

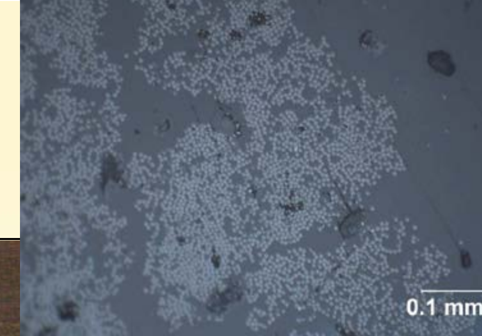


Tapes, Woven Fabrics

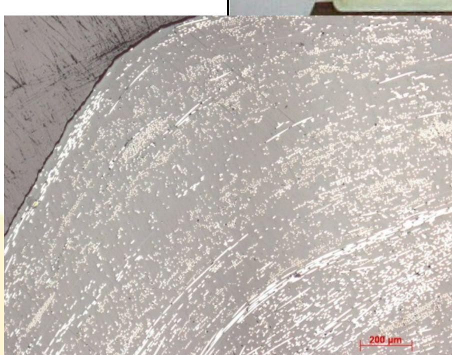
Material Transitions



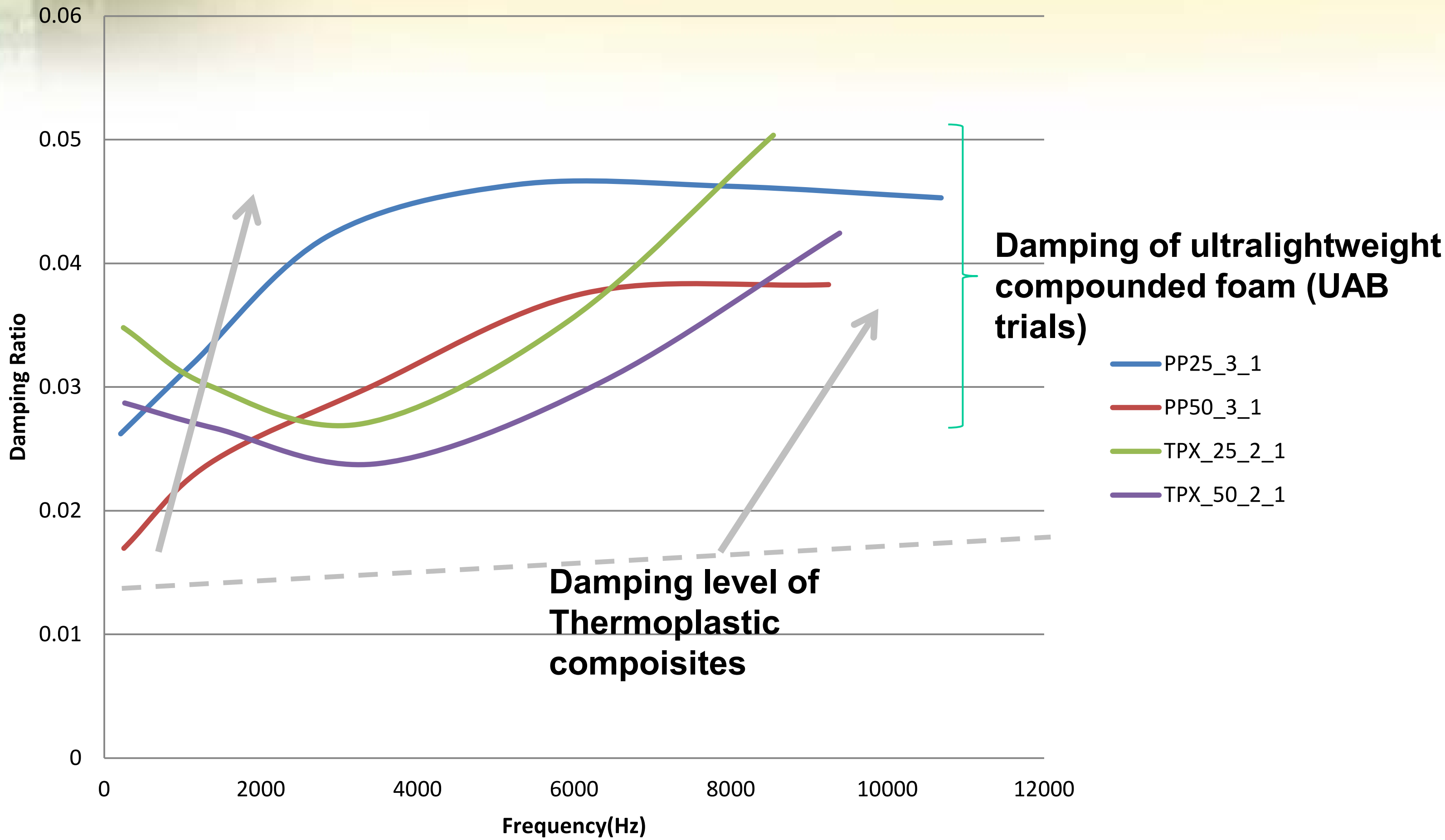
Chopped Pellets



Charge / Shot



Damping enhancement possibilities by ultra lightweight compounded foam



Significant enhancement of damping capacity by the compounded foam materials. While we are in the process of quantifying between the variants, all variants show multifold increase in damping, therefore promise for enhanced crashworthiness in automotive applications