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

GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

This presentation does not contain any proprietary or confidential information

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Project Summary

Timeline
Project Start - Oct 2011
Project End – Sep 2016
35% complete

Budget
Total project: $750,000
DOE portion: $600,000
University Cost Share: $150,000
$314, 526 DOE
$215,050 Expended
35% complete

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

Partners
- MIT-RCF
- Laurel Biocomposites
- e-Spin
- CIC, Canada
- Toray Carbon Fibers

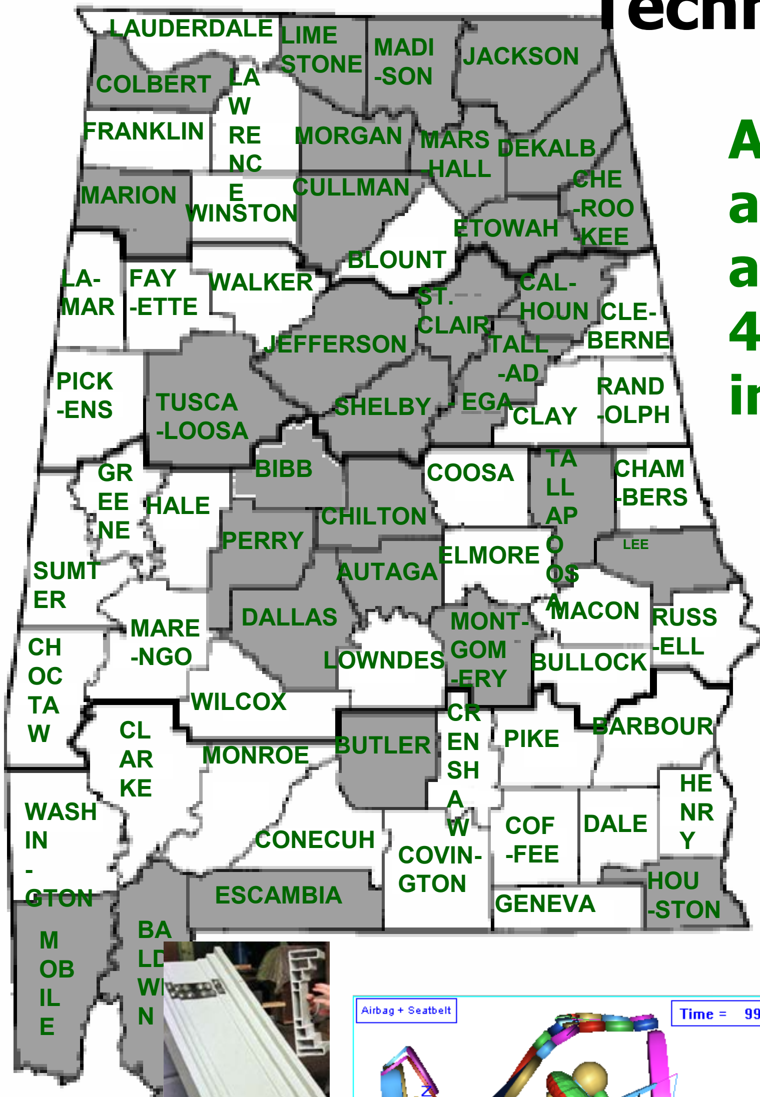
DOE GATE Relevance and Goals (Consistent with VTP Goals)

- 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.
- Train and produce graduates in lightweight automotive materials technologies
- Structure the engineering curricula to produce specialists in the automotive area
- Expose minority students to advanced technologies early in their career
- Develop innovative virtual classroom capabilities tied to real manufacturing operations

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

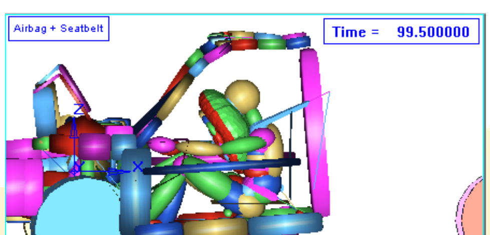
- 20,000 sq.ft of industry scale facilities
- Rapid technology transition to industry – defense, transportation, infrastructure, aerospace and marine
- Strong industry partnerships with materials suppliers, integrators and end users; more than 20 active NDA's
- Partnerships with federal & state agencies,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

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.

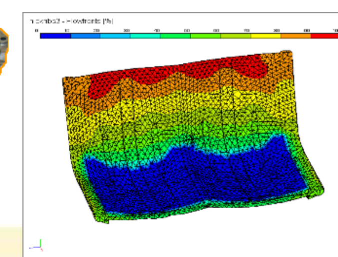
- Training students in advanced lightweight materials and manufacturing technologies.
- Design and manufacturing of future generation transportation, including automobiles, mass transit and light, medium and heavy trucks.



Modeling of crash & protective padding

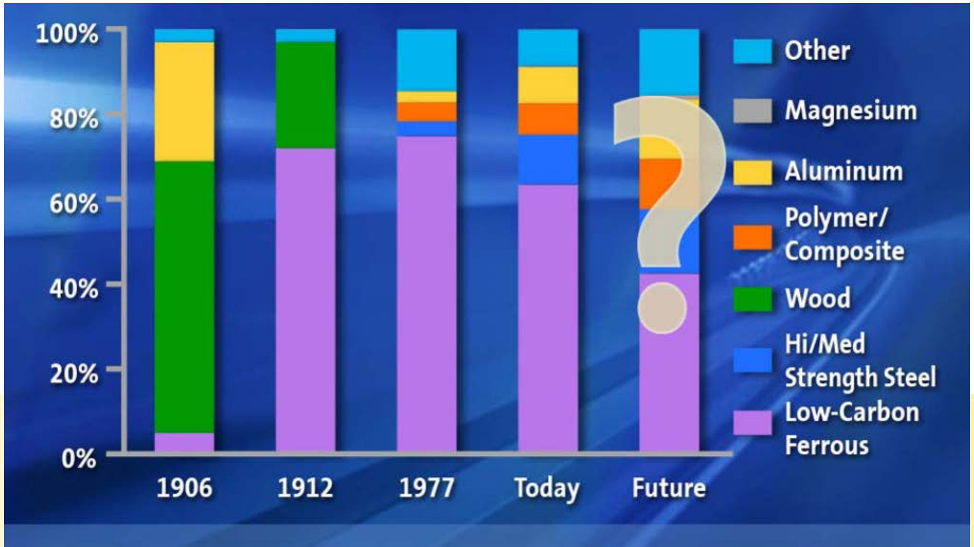

High speed computational facility


Automotive castings


Process modeling

Weight reduction – Automotive, Mass Transit and Truck

- Performance
- Increased 'customer value' while staying within Corporate Average Fuel Economy (CAFÉ) limits
- Long term increase in fuel prices
- 6-8% (with mass compounding) increase in fuel economy for every 10% reduction in weight, everything else being the same



DOE, Carpenter, 2008

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

Materials Science & Engineering/MPAD	Mechanical Engineering	Biomedical Engineering	Civil and Environmental Engineering
Lightweight Composites and Castings – Materials and Manufacturing R&D	High-fidelity modeling and simulation; predictive Engineering, material models	Crash & injury studies, Studies for protection using lightweight advanced materials	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

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

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 Directly Funded Students (2011-2012)

GATE – Graduate scholars

	GATE Scholar	Department and Standing	GATE Thesis / Research
1	Melike Dizbay-Onat	Interdisciplinary Engineering, Pursuing 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	Theresa Bayush	Materials Science & Engineering, PhD	Natural fiber composites

GATE Team for Industry Support

Alejandra Constante, Theresa Bayush, Arabi Hassen, Samuel Jasper, Danila Kaliberov, Benjamin Willis, Qiuishi Wang, Ranae Wright, Peter Barfknecht,

GATE – Undergraduate scholars pipeline

	GATE Scholar	Department and Standing	GATE Research
1	William Warriner	Materials Science & Engineering, Junior	Extrusion-compression molding of long fiber thermoplastics
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	Emily Willis	Collaborating High School, Hoover High	Pull-out strength of screws from thermoplastic composite plates

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

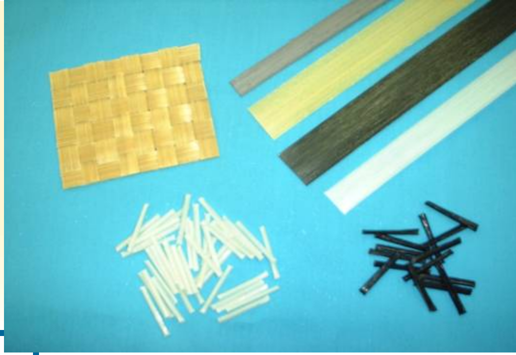
GATE courses

- **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
- Mechanical Characterization and Performance Evaluation of Advanced Lightweight Materials
- Advanced Composite Mechanics
- Nano materials for Automotive Applications.
- Process Quality Engineering
- Nondestructive Testing & Evaluation

- Carbon Fiber Technologies for Automotive
- 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. 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**

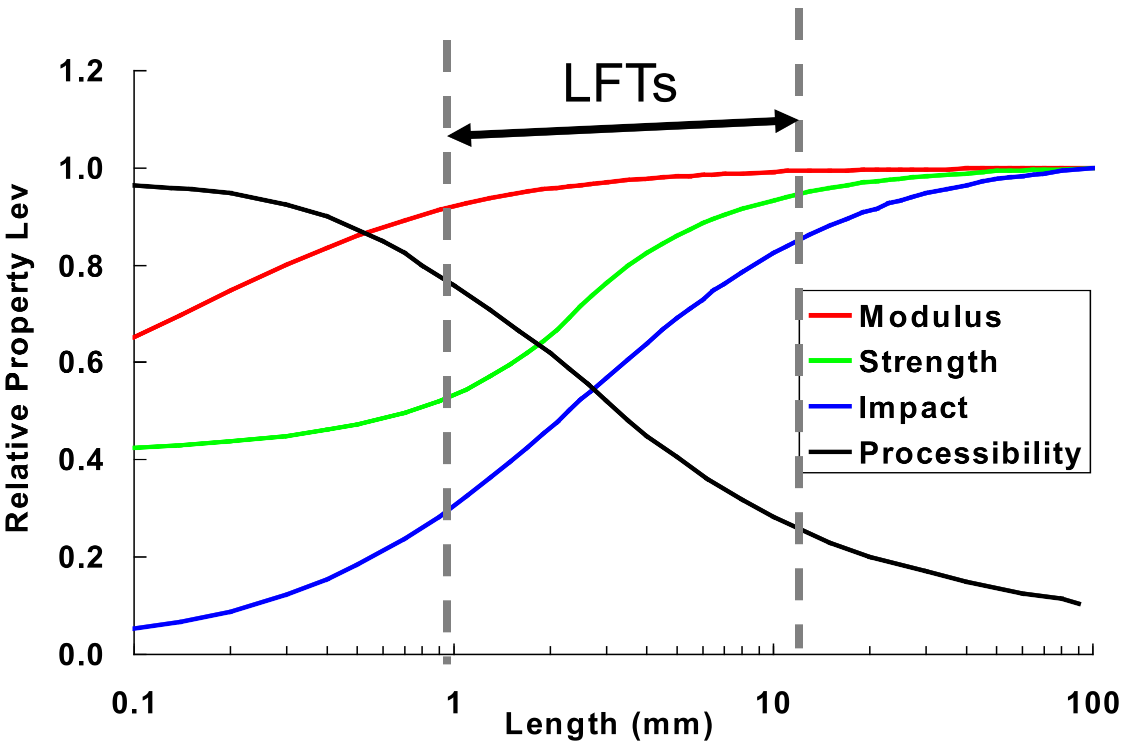
FORMING AND FINISHING OPERATIONS

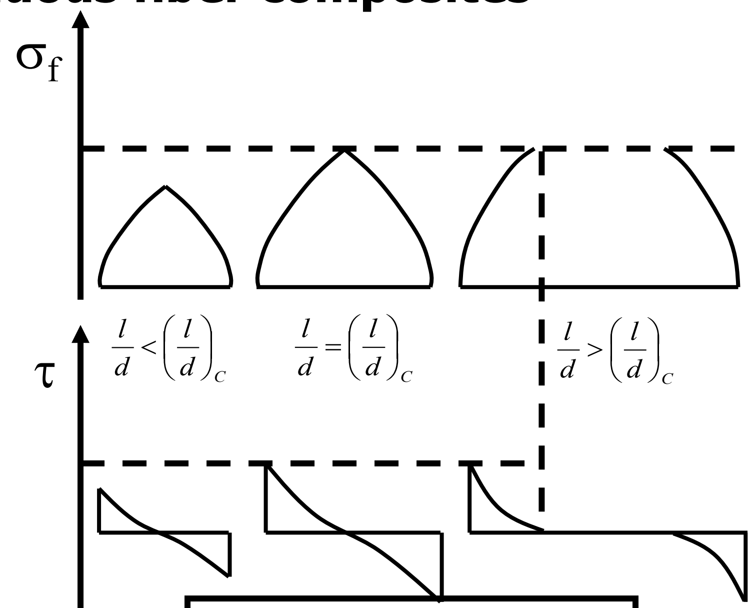
(FIBER INJECTION MOLDING, EXTRUSION, COMPRESSION MOLDING, PULTRUSION, DIAPHRAGM FORMING, THERMOFORMING, ETC…)

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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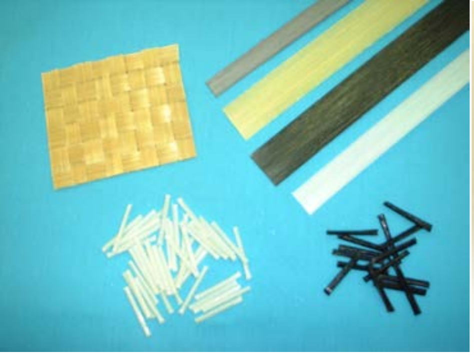
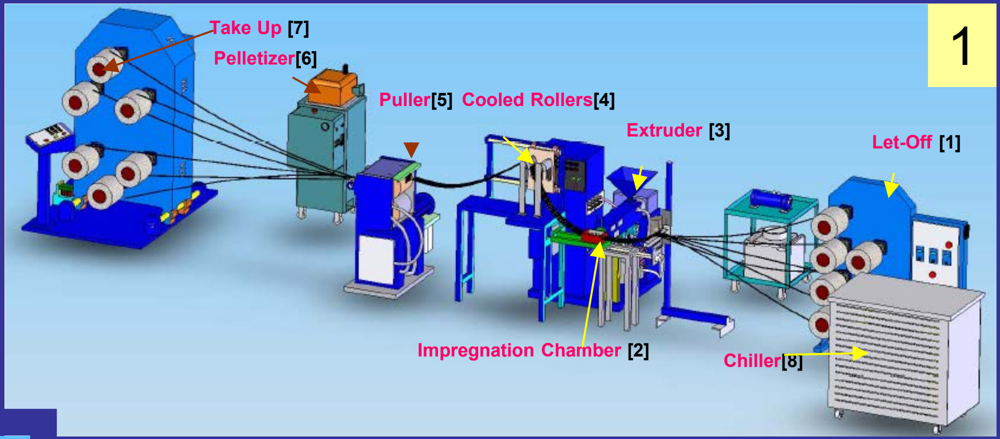
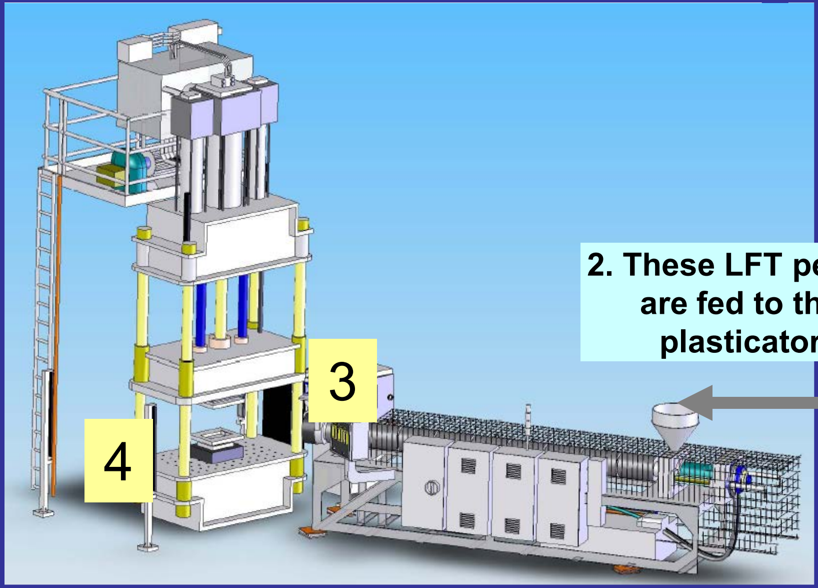
Long Fiber Thermoplastic (LFT) Composites Processing Technology



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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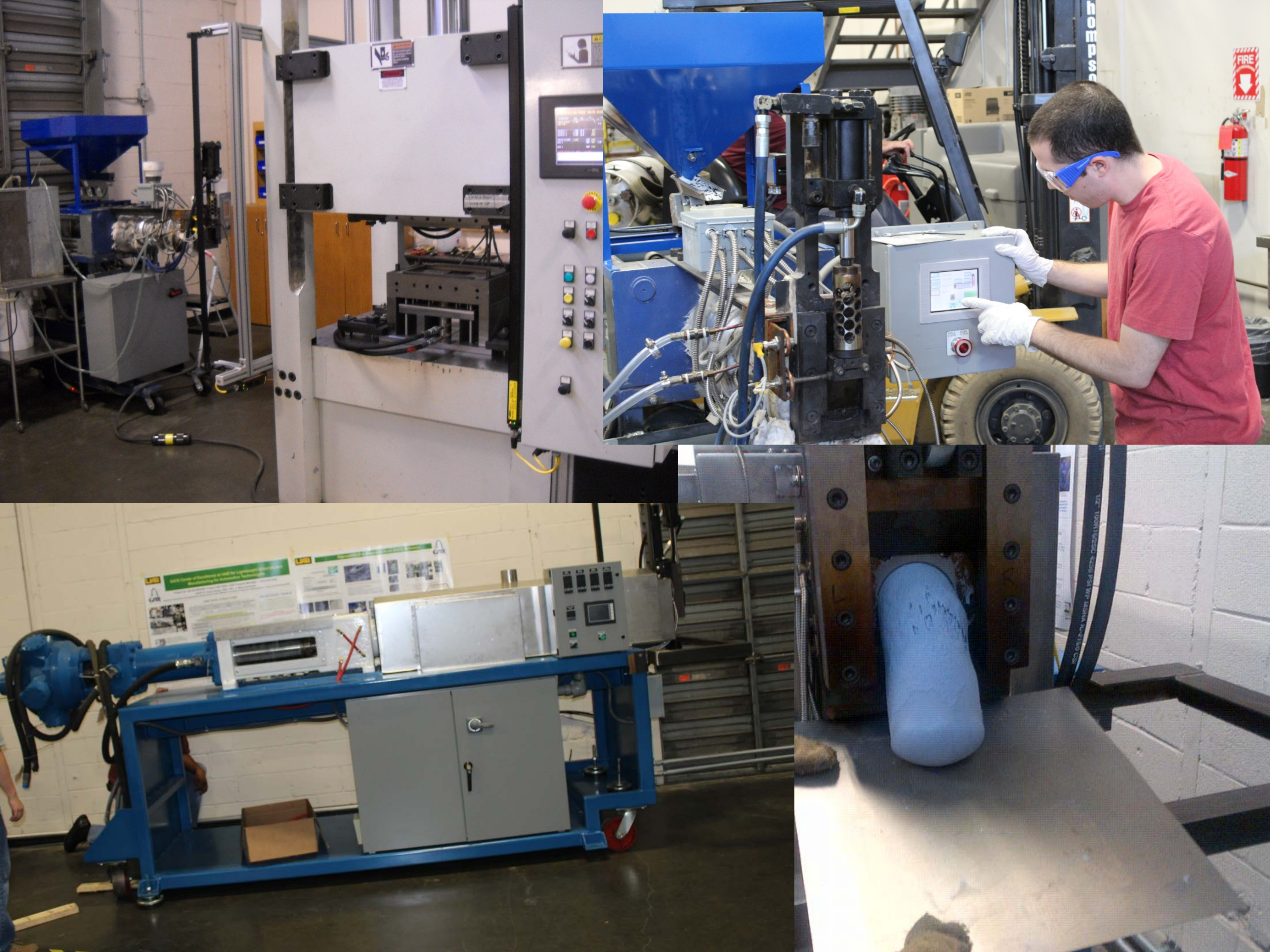
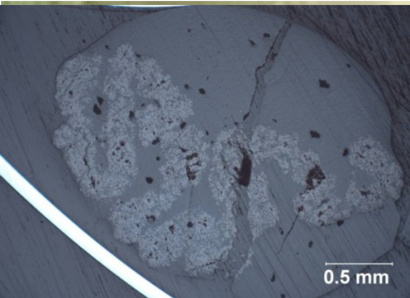
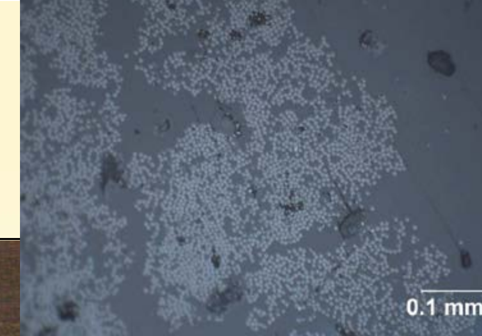

FIRE

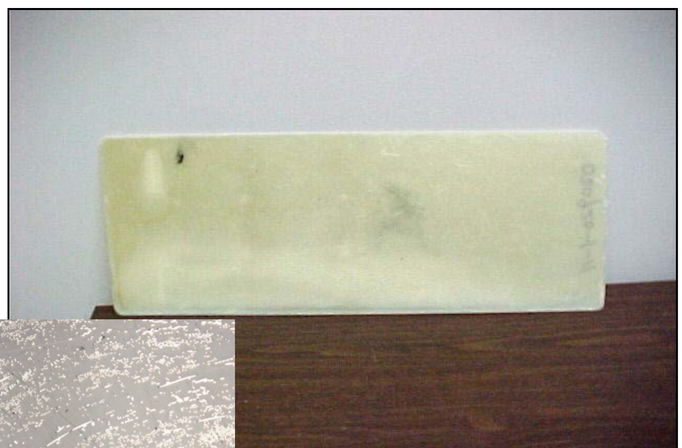
Material Transitions

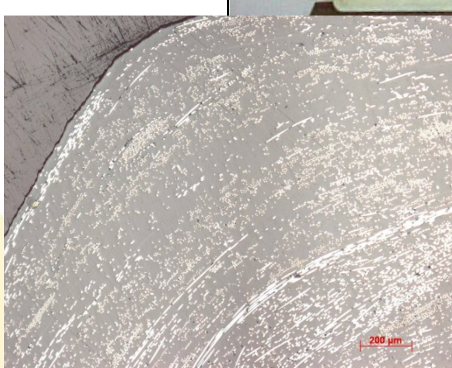


Chopped Pellets



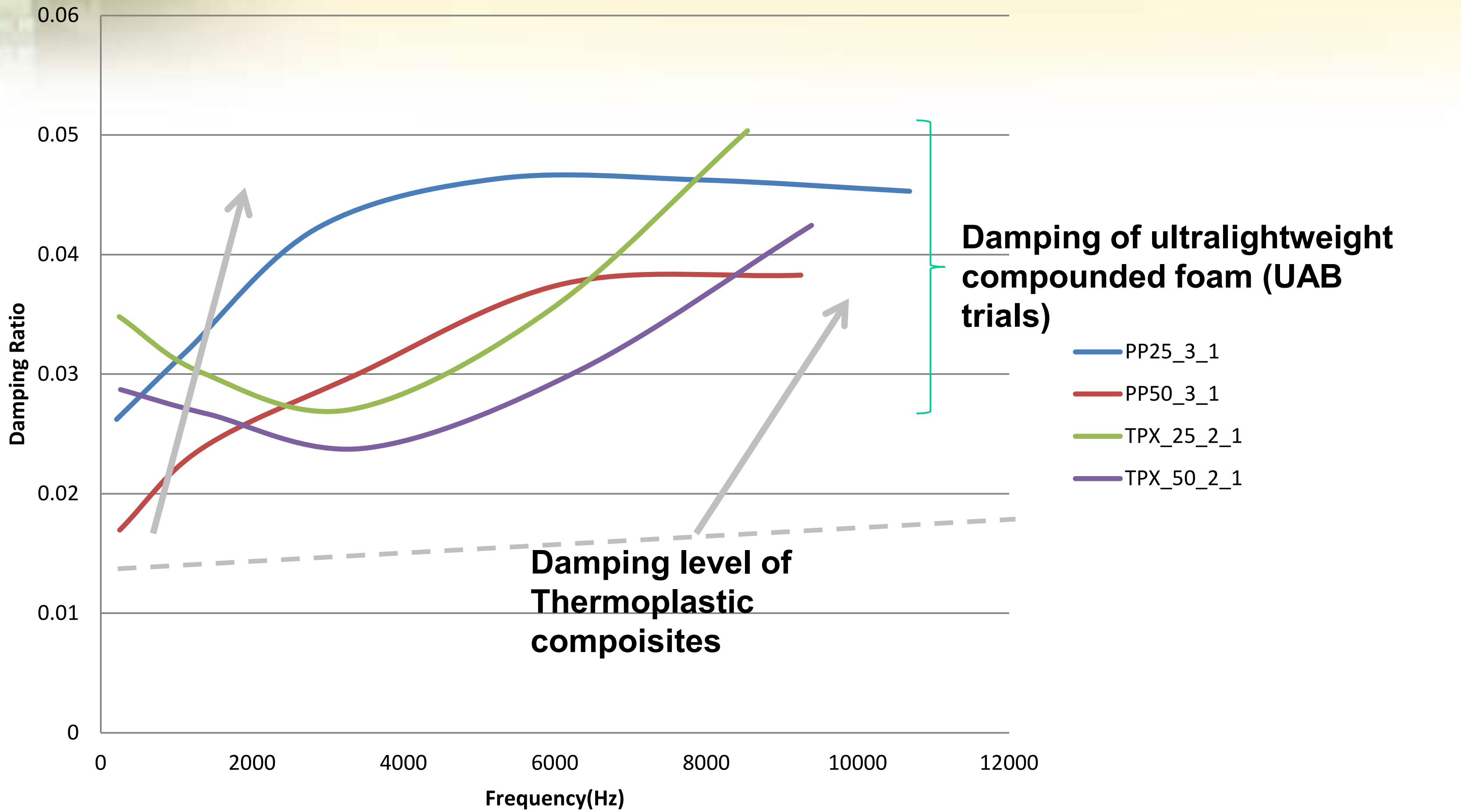
Charge / Shot





Compounding Micro-Sphere Pellets

Damping enhancement possibilities by ultra lightweight compounded foam

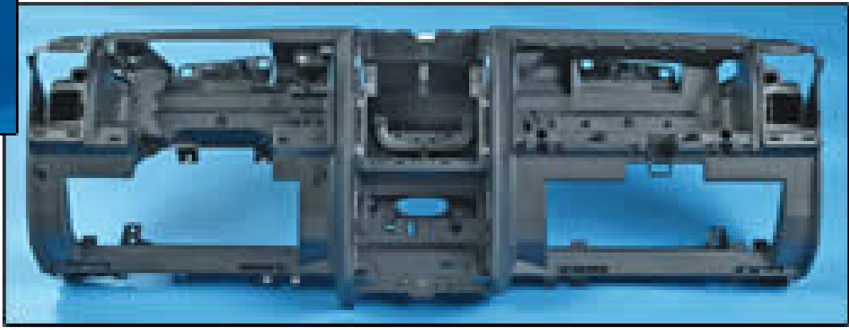


Significant enhancement of damping capacity by the compounded foam materials. While we are in the process of quantifying between the variants, all variants show multifold increase in damping, therefore promise for enhanced crashworthiness in automotive applications

Thermoplastic Composites in Automotive & Mass transit

Injection-molded concentric slave cylinder used in the automotive industry

Headliner of the 2007 Honda Acura MDX



Long glass/PP structural duct : 2007 Dodge Nitro SUV

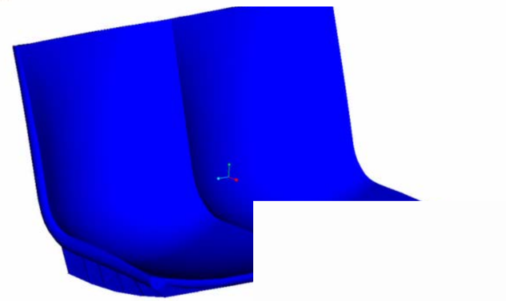
All-terrain vehicle (ATV) footwell

Brake sensor housing for the automotive industry

Wiper pivot housing used in automotive industry

Source: Ticona

Composites for Mass Transit Bus



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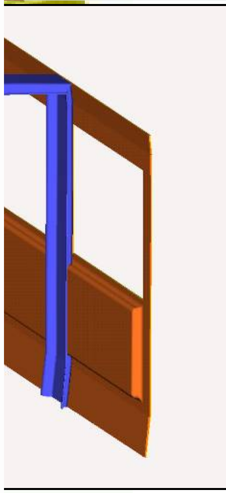

Body
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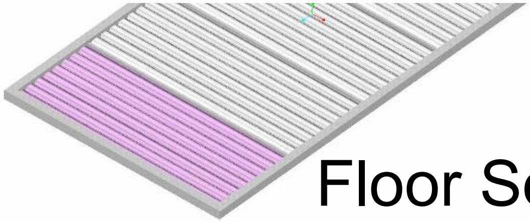
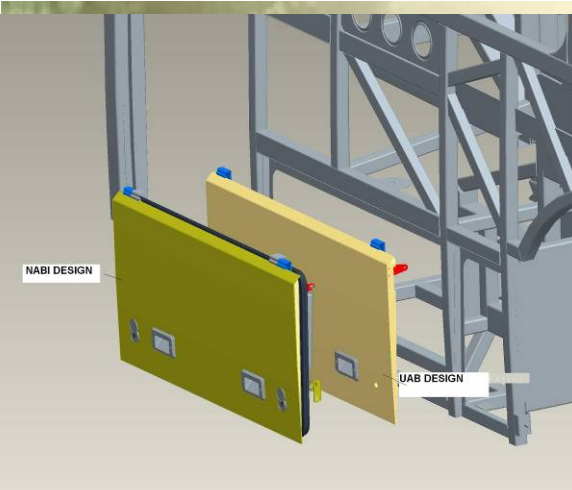
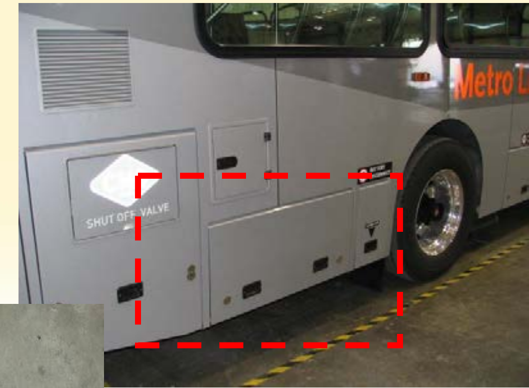
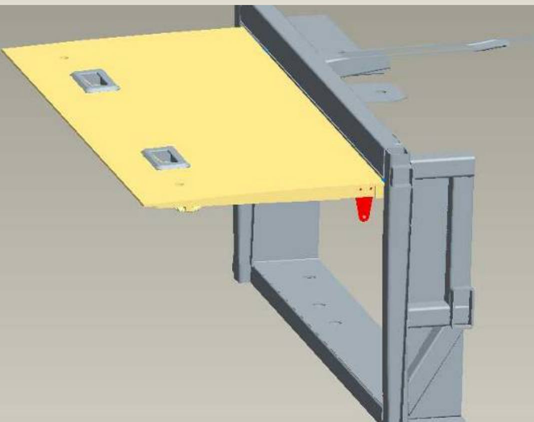


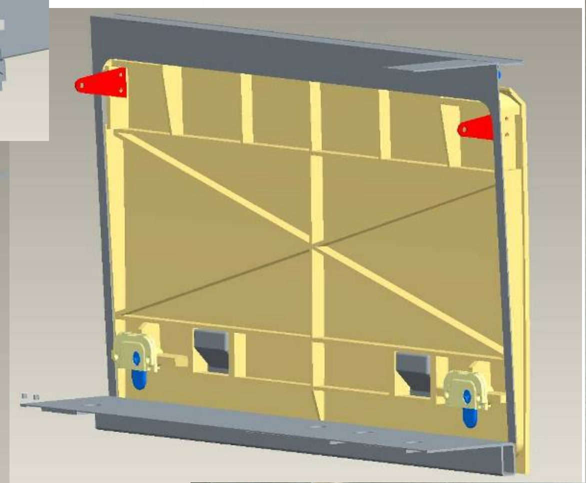
Floor Segment

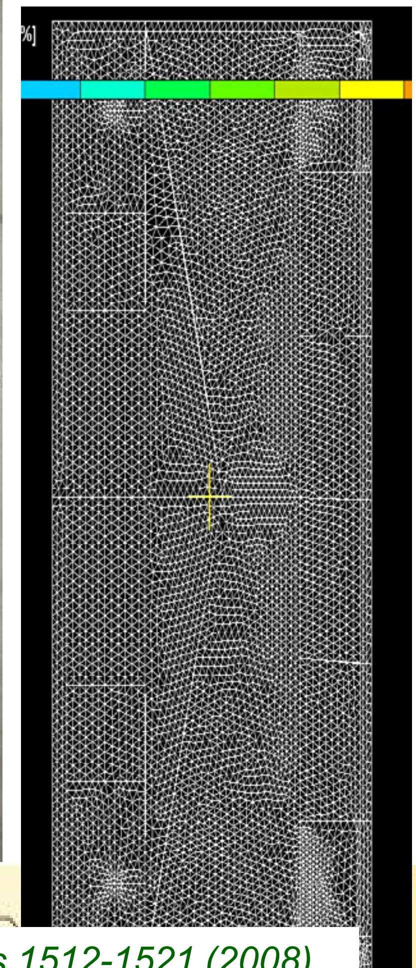
Access Doors (Passenger and Military Vehicles)

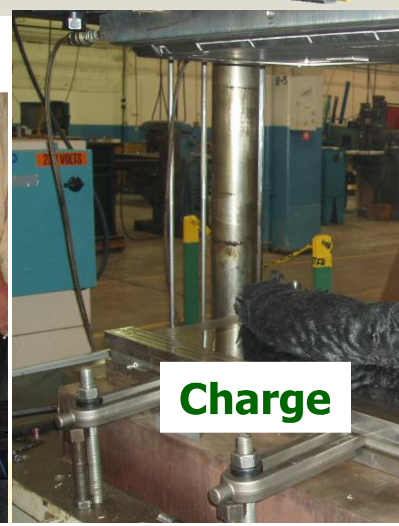






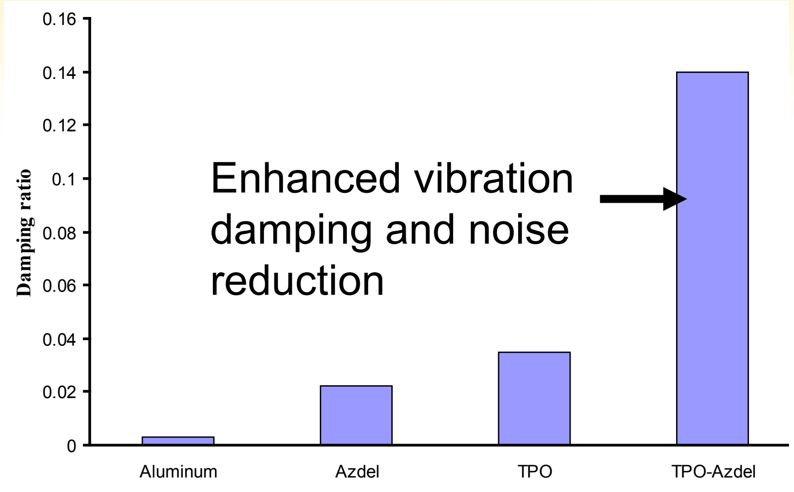






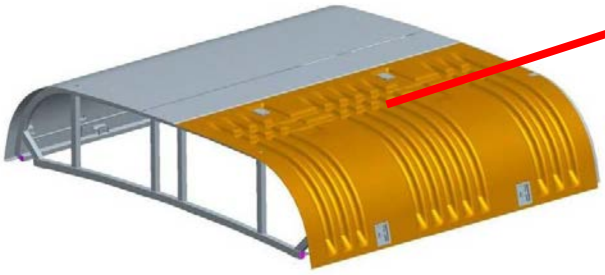
Composites Part A: Applied Science and Manufacturing*, Volume 39, Issue 9, Pages 1512-1521 (2008).*

40% lighter Roof Door for Vehicle; Weight reduction - 450 lbs



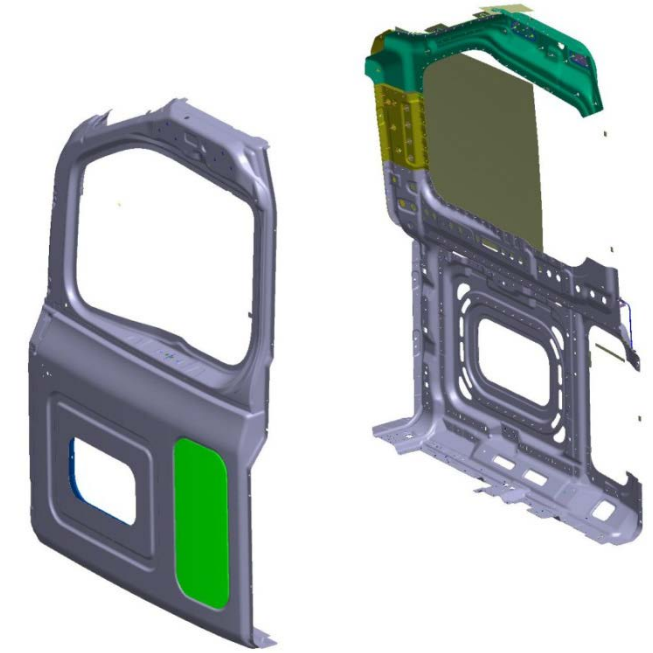
- Thermoplastic composite technology demonstrated on a large scale part; Innovative utilization of synergistic materials
- Form-fit function; including existing hardware
- 39% weight reduction & 77% less free standing deformation
- Order of magnitude improved vibration damping Lowering of Center of Gravity. The BRT bus has ~8 roof doors per segment –potential weight savings 450 lbs
- Cost effective manufacturing – reduced assembly steps
- Generic to military, light rail, trucks and other vehicles

AC roof cover door



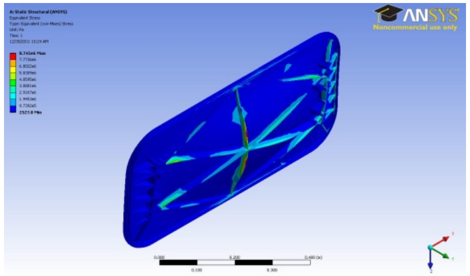
Materials & Design, Volume 30, Issue 4, Pages 983-991 (2009).

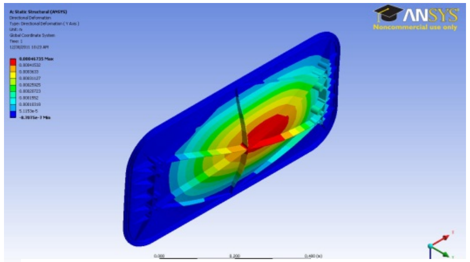
Composite Door for Truck



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%**



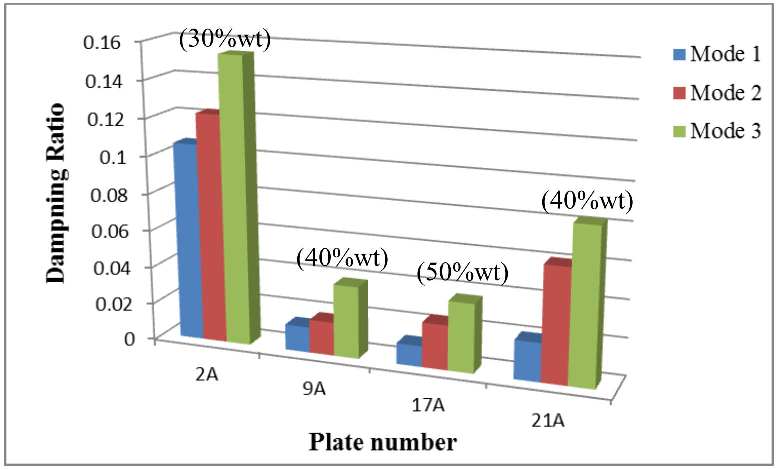


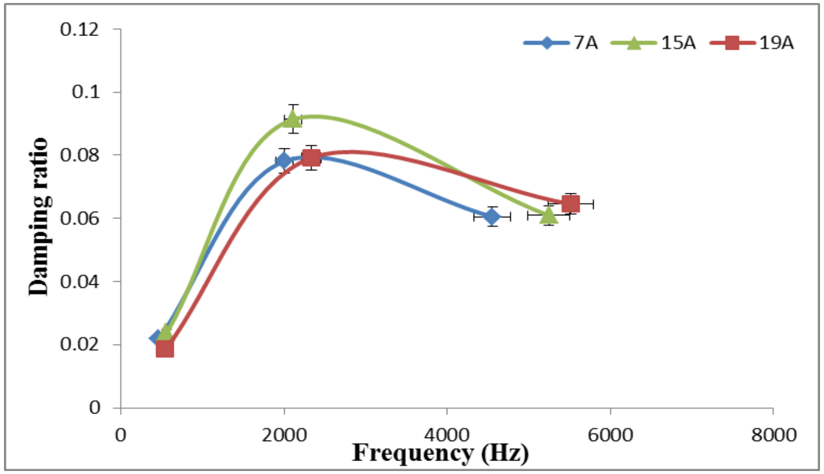
- Maximum stress: 8.7 MPa
- Max deflection: 0.47 mm
- Mass: 1.84 kg
- Weight saving: 26.4%

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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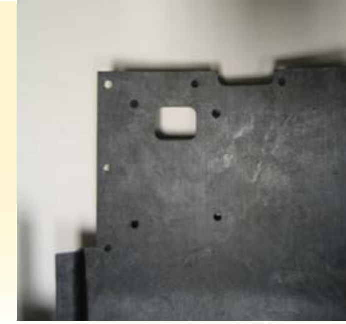
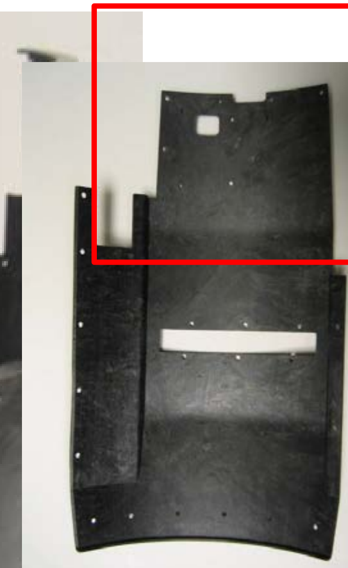
Thermoplastic Composite Shell and Baseplate used for Electronic Modules



Composite Baseplate

Composite Aeroshell



Patent No: 8,277,933 - USPTO

Complex shapes in carbon thermoplastic in < 1 minute cycle times – Manufacturability trials with MIT-RCF

Integrated EMI Shielding

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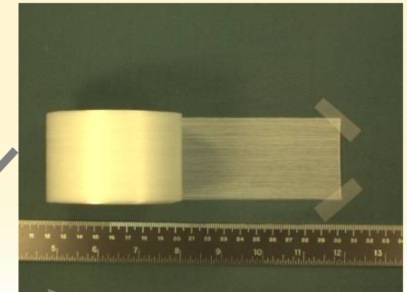
LFT Co-molded with Continuous Thermoplastic Tapes

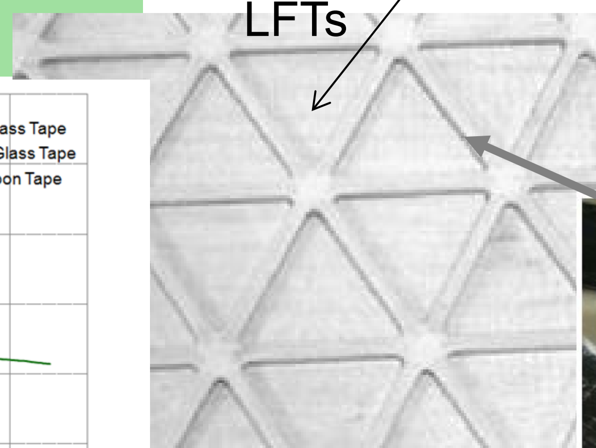
- Co-molding LFT with pre-consolidated / continuous reinforced tape
- Local reinforcements
  - Replace traditional rib structures
  - Local tailored strength & stiffness
  - Functional integration
- Parameters influencing final properties
  - Processing
  - Bonding interface
  - Stiffness of the materials
  - Thickness ratio

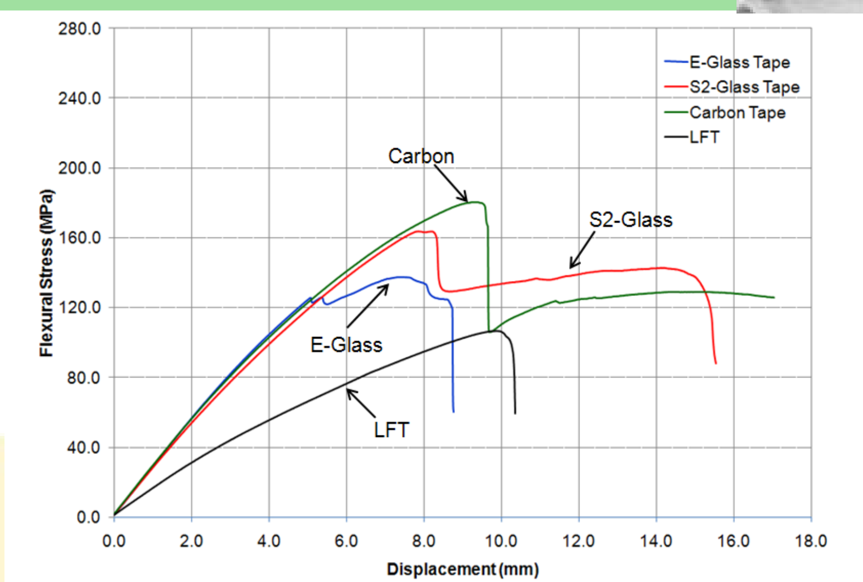


Continuous Tapes

LFT

Co-molded LFTs

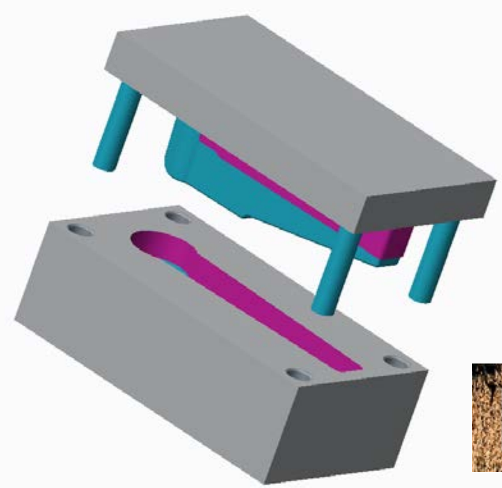




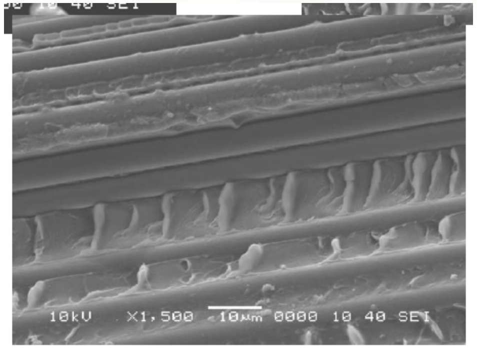
Polymer Composites, In-print, Jan 2013

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.

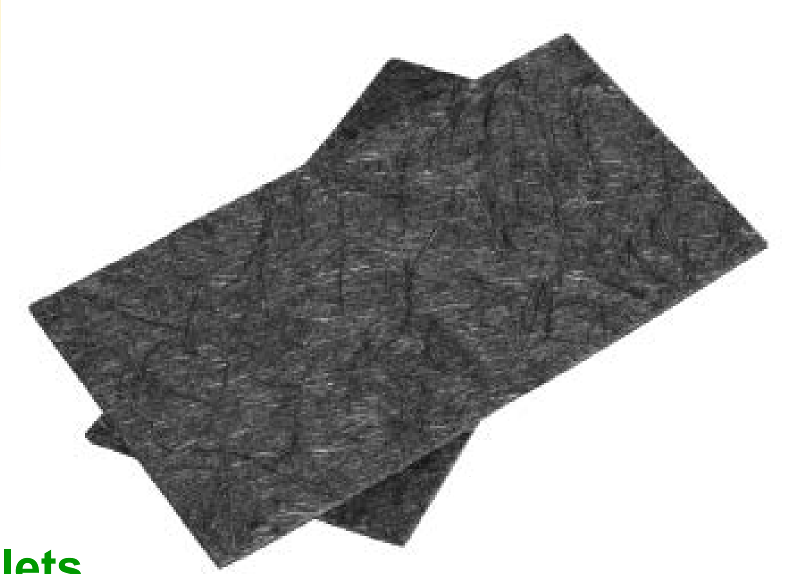


Representative Material Forms

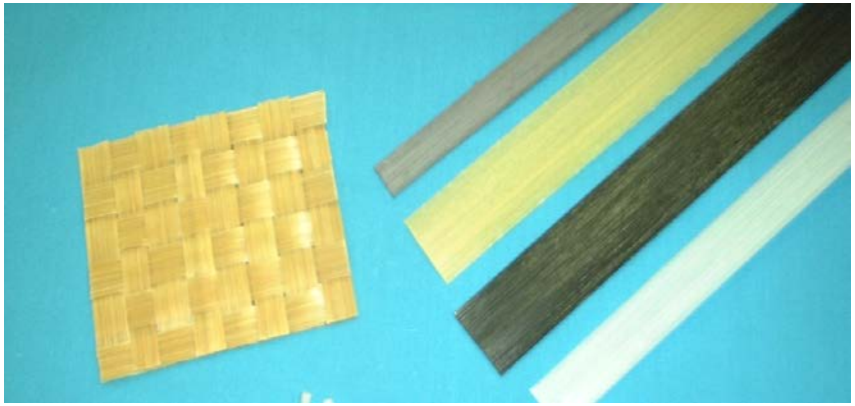


Intimate wet-out

Simple blends, hot-melt pellets



Wet-laid or roll bonded



Tapes, Woven Fabrics

Future Work

- Leverage GATE and expand industry partnerships
- Carbon fiber thermoplastic impregnation studies for PP, nylon and PPS
- Further processing, test data and design parameters for recycled carbon fibers
- Compounded recycled carbon fibers for injection and compression molding
- Interaction with Oak Ridge on specific projects

Summary

- Selective insertion of cost-effective, lighter, high performing, mass produced composite parts for automotive and transportation.
- Next generation work-force development
- Materials and process innovations
- Applications developed ready for commercialization.
- The applications developed are generic for marine, aerospace, medium/heavy vehicles and energy sector.