GATE Center of Excellence at UAB in Lightweight Materials for Automotive Applications

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This presentation does not contain any proprietary or confidential information

Materials Processing and Application Center (MPAD) - Composites at UAB

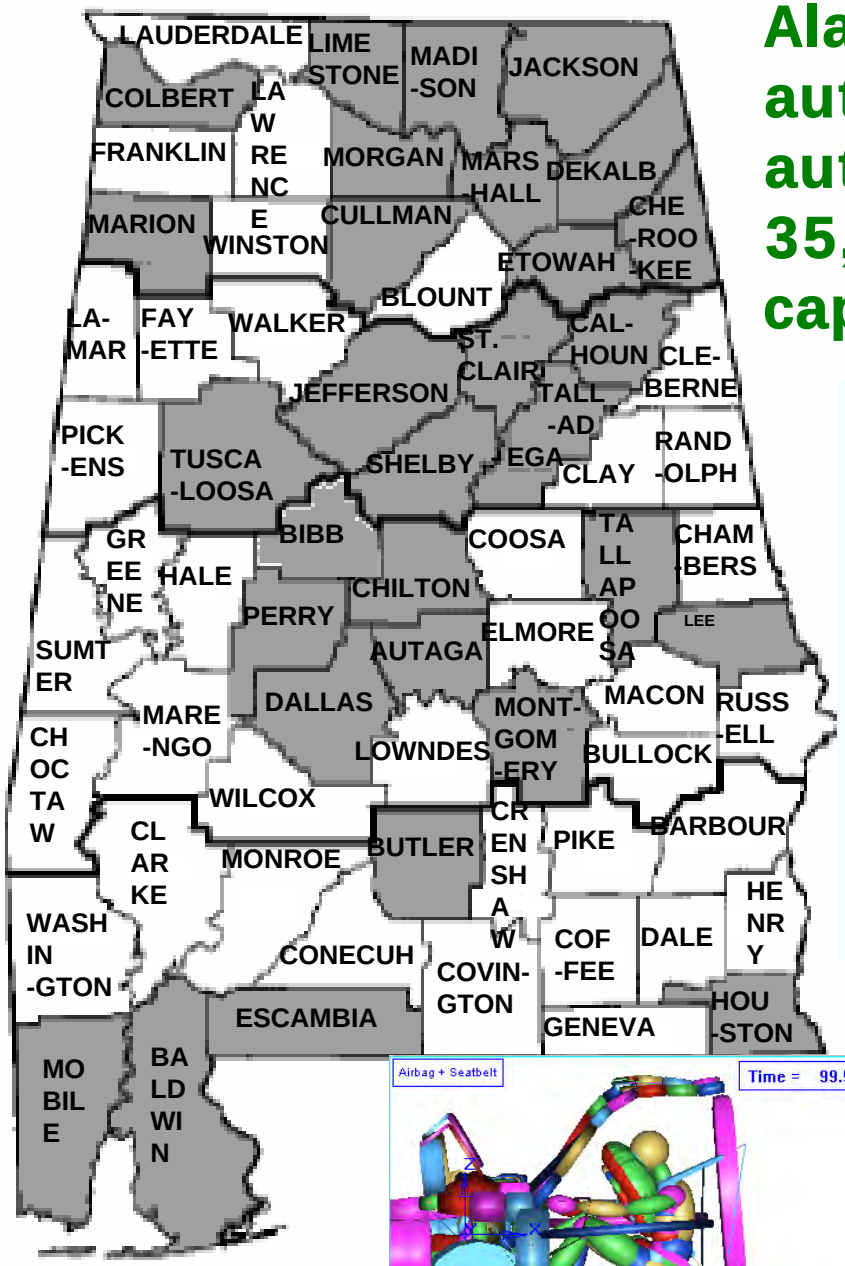
DOE GATE Center of Excellence for Lightweighting materials

20,000 sq.ft dedicated R&D facilities

Applications Development and Prototyping with Composites and Lightweight metals

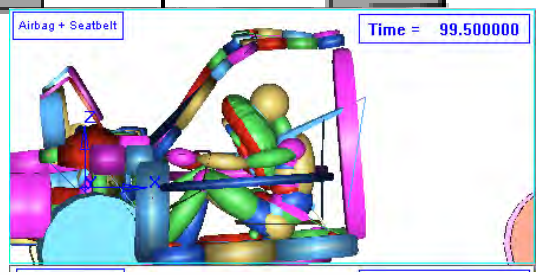
Automotive Industry Impact in the State of Alabama

DOE Merit Review
May 2011



Alabama has a rapidly growing automotive industry. Since 1993 the automotive sector has created more than 35,000 new jobs and $6.4 billion in capital investment in Alabama.

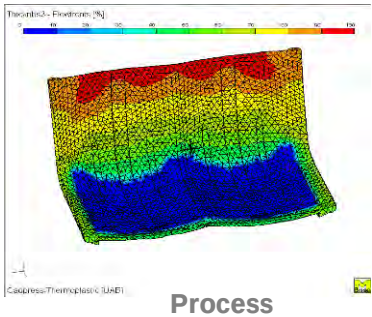
The UAB GATE center is focused on training students in advanced lightweight materials and manufacturing technologies. Recent developments in low-cost composite materials and lightweight castings and fabrication technologies offer excellent potential for design and manufacturing of future generation transportation, including automobiles, mass transit and light, medium and heavy trucks.



Modeling of crash & protective padding

High speed computational facility

Automotive castings



Process modeling

Relevance and Goals

Overall FCVT Goal

- "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 FCVT 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.

Structure of the UAB GATE Center

UAB Materials Science & Engineering

- Advanced lightweight composite materials for vehicles
- Automotive Castings

UAB Civil & Environmental Engineering

Lightweight materials for energy absorbing guard rails and bridge repair/retrofit

UAB Biomedical Engineering

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

UAB Mechanical Engineering

High fidelity modeling & simulation of crashes, material process models and structural analysis

Miles College

- Minority institution partner
- Pipeline to UAB programs & graduate school

UAB GATE (DOE CENTER OF EXCELLENCE)

GATEWAY TO THE FUTURE
GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

Lawson State, Calhoun & Jeff State Community College

- 2-year automotive degree
- Pipeline to UAB and automotive industry

Alabama Based Automotive Companies

- Honda, Mercedes, Hyundai, Toyota
- Plastics molders

National Labs & State

- Oak Ridge
- ALDOT

Small Businesses

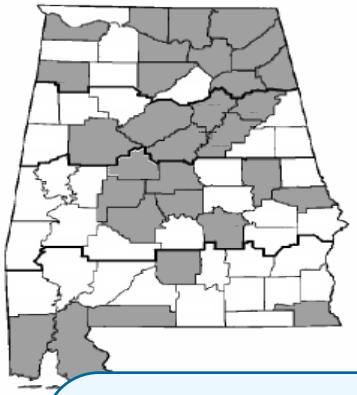
- Coosa Composites
- Glasforms
- Britt & Co.
- Biomedical Co.

UAB GATE Objectives

Year 5 Objectives

- GATE scholars work compilation by July 2011
- GATE course offerings in the sequence established over the 2005-2010 time frame (six courses offered at least twice over the GATE cycle)
- Brief advisory board on accomplishments of the GATE program in its first 5-year funding cycle
- Continue to offer real and virtual classroom experience
- Expand undergraduate pipeline to graduate GATE scholars
- Coordinate and offer workshops and research training for high school, community & undergraduate students pipeline
- Hold Advisory Board meetings
- Tour industry sites and expand industry interaction

Graduate Automotive Technology Education (GATE) Center of Excellence in Lightweight Advanced Materials Technologies



Alabama has a rapidly growing automotive industry. Since 1993 the automotive sector has created more than 35,000 new jobs and $6.4 billion in capital investment in Alabama.

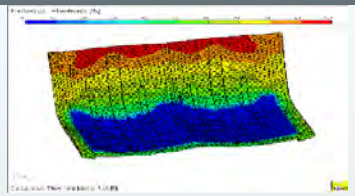
The UAB GATE center is focused on training students in advanced lightweight materials and manufacturing technologies for automotive and related sectors.

Pay-offs: Low-cost composite materials and lightweight castings and fabrication technologies, design and manufacturing of future generation automobiles, mass transit and light, medium and heavy trucks.

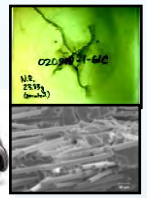
UAB GATE PARTNERS

- UAB School of Engineering (Materials Science & Engineering, Mechanical Engineering, Biomedical Engineering, Civil Engineering)
- Alabama Automotive Companies (Honda, Mercedes, Hyundai etc)
- National Composite Center, Kettering, Ohio
- Miles College, Lawson State Community College, Heritage Center
- Small Businesses (Castings, Plastics and Composites Manufacturer's)
- DOE Oak Ridge National Laboratory
- Society for Plastics Engineers

REPRESENTATIVE GATE STUDENT PROJECTS



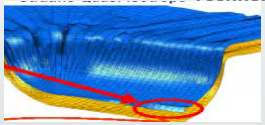
Composite materials processing technologies for automotive & mass transit applications



Long Fiber Thermoplastics – Processing & Performance Evaluation

Automotive Castings Technologies

Focus on lightweight automotive technologies

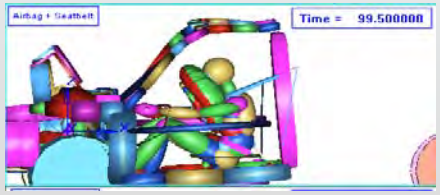


Thermoforming and Process Simulation

Graduate Automotive Technology Education (GATE) Program

Virtual class room, High Speed Computation and Modeling

Composite Guardrails for Highway Safety



Modeling of crash & protective padding

Approach to Meet Objectives (including targets)

- Support 3 graduate students/year (two supported by DOE and one cost shared by UAB) with research projects focused on automotive applications
- Support 4 undergraduates each year in automotive related research
- Develop and offer six new automotive related courses with the potential to impact 20 – 30 students per year
- Influence at least 30 students per year through hands-on workshops
  - Undergraduate students (promote interest in graduate studies)
  - High school students (promote interest in the automotive area)
  - Include a focus on minority students (tap into a larger workforce)
- Interact with industry through Advisory Board Memberships, tours of their facilities, collaboration through the virtual classroom concept, and interaction on research projects (including SBIRs and STTRs)
- Briefings and visits to OEMs and suppliers on GATE program

Accomplishments and Progress: GATE Directly Funded Students (2005-20010)

DOE Merit Review
May 2011

	Student Name	Department and Standing	Thesis / Research
1	Mohammed Shohel	Civil and Environmental Engineering, PhD (Graduated, Dec 06)	Resin infusion processing of laminated composites
2	Carol Ochoa	Materials Science & Engineering, PhD (Graduating, Dec 09)	Finite element analysis and modeling of thermoplastic composites
3	Balaji Venkatachari	Mechanical Engineering, PhD	Simulation of flow fields in automotive bodies
4	Amol Vaidya	Civil & Environmental Engineering, PhD (Graduated, May 09)	Sandwich construction for crashworthiness of automotive applications
5	Lakshya Deka	Materials Science & Engineering, PhD (Graduated Dec 08)	LS-DYNA modeling of of thermoplastic composites
6	Satya Vaddi	Materials Science & Engineering, MS (Graduated May 09)	Fire behavior of thermoplastic composites
7	Felipe Pira	Materials Science & Engineering, MS	Process Modeling of Thermoplastic Composites
8	Leigh Hudson	Materials Science & Engineering, MS (Graduating Dec 09)	Pultrusion of thermoplastic composite elements
9	Lina Herrera-Estrada	Materials Science & Engineering, MS (Graduated, May 09)	Banana Fiber Composites for automotive applications
10	Danila Kaliberov	Materials Science & Engineering; MS	Threaded long fiber thermoplastic composites
11	Michael Magrini	Materials Science & Engineering, MS (Graduated BS May 08; continued as graduate student)	Impact response of long fiber and laminated thermoplastic composite materials
12	Milike Onat	Interdisciplinary Engineering, PhD (Joined Dec 09)	Carbon footprint reduction and emission absorpbtion activated carbon composites
13	Aaron Siegel	Materials Science & Engineering, PhD Joined Fall 2010	Energy absorbing compounded thermoplastic foams for enhanced crashworthiness
14	Peter Barfknecht	Materials Science/Biomedical Engineering, PhD, Joined Fall 2009	Carbon fiber sizing and liquid molding of reactive thrmoplastics
15	Nsiande Mfala	Materials Science & Engineering, MS Joined Spring 2011	Nanostructured kenaf and banana fiber thermoplastic composites for automotive applications
16	Benjamin Geiger-Willis	Materials Science & Engg. MS joining Summer 201	High strain rate impact of thermoplastic composites and foams for crashworthiness

GATE: Undergraduate Student Pipeline

1	Malina Panda	Senior, Materials Science & Engineering (Graduated, May 07)	Development of hot-melt impregnated materials
2	Daniel Kaliberov	Junior, Materials Science & Engineering	Vibration testing of long fiber thermoplastic composites
3	Michael Magrini	Senior, Materials Science & Engineering	Impact response of long fiber and laminated thermoplastic composite materials
4	Michael Entz	Senior, Materials Engineering	Impact analysis of laminated composites
5	V. Ameya	Sophomore, Auburn University	Self reinforced polypropylene studies
6	Hadeel Abdelmajeed	Senior, Materials Science & Engineering	Thermoforming processing of laminated composites
7	Walter Malone	Sophomore, Materials Science & Engineering	Sandwich panel construction for automotive floor boards
8	Victor Long	Sophomore, Materials Science & Engg.	Compression after impact of layered materials
9	David Sexton	Junior, Materials Science & Engineering	Carbon fiber thermoplastic impregnation
10	Saptarshi Vichare	Junior, Mechanical Engineering	Carbon fiber thermoplastic impregnation
11	Benjamin Rice	Senior, Rhodes College, Memphis (Summer 08)	Compression after impact of E-glass/vinyl ester composites
12	Khongor Jaamiyana	Senior, Colorado State Univ (Summer 08)	Low velocity impact response of Carbon SMC
13	Alex Johnson	Sophomore, Auburn University	Carbon fiber impregnation and characterization
14	Krishane Suresh	Oak Mountain High School	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	Junior, Materials Science & Engg.	Long fiber thermoplastic fiber orientation studies
18	William Warner	Junior, Materials Science & Engg.	Nondestructive evaluation of defects in sandwich composites
19/ 20	Nsiande Mfala & Theresa Bayush	Senior, Materials Science & Engg.	Nanonstructured banana fibers thermoplastic composites for automotive applications
21	Benjamin Geiger-Willis	Seniors, Materials Science & Engg.	Designand Construction of a Split Hopkinson Pressure Bar for high strain rate impact testing of materials

GATE fellows to date (2006-present)

- 16 graduate students (9 MS + 7 PhD)
  - Partially or fully funded by DOE GATE
  - Research dissertation/thesis focus on GATE topics
  - Peer-reviewed research publications & papers

- 21 undergraduate students (Junior/Senior/High School)
  - Work study students serve as pipeline for graduate program & GATE fellows (Benjamin Willis and Theresa Bayush are joining graduate program based on work done as GATE undergrad scholars)
  - Participate in poster competitions and undergraduate research forums

Accomplishments and Progress: GATE Courses Developed & Offered

GATE COURSES

- ☑ MSE 635/735: Advanced Composite Mechanics (Offered twice)
- ☑ MSE 634/734: Design & Mfing Technologies for Automotive Applications (Offered twice)
- ☑ MSE 667/767: Process Modeling and Simulation for Lightweight Materials (Offered twice)
- ☑ MSE 490/590: Nanomaterials for Automotive Applications (Offered twice)
- ☑ ME/MSE/CEE: Mechanical Characterization & Performance Evaluation of Advanced 690/790A Lightweight Materials (Offered twice)
- ☑ BME/MSE/CE: Optimized Lightweight Materials for Improved Protection (Summer 2011)
- ☑ MSE 433/533 Nondestructive Evaluation (Offered twice)
- ☑ MSE 614/714 Process Quality Engineering

AUTOMOTIVE CERTIFICATE (GATE Graduate Fellows)

"Automotive Certificate" issued at the department level for GATE graduate fellows who have

1. Met the requirements for a graduate degree
2. Taken at least 4 GATE courses
3. Completed a research project tied to the automotive or transportation area

AUTOMOTIVE CERTIFICATE (Undergraduate GATE fellows)

A participation certificate is issued to undergraduate students who participate in GATE projects or work on senior design related to automotive projects.

The UAB GATE center has expanded its activities to Technology Training for the Industry

DOE Merit I
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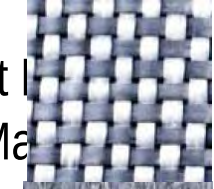
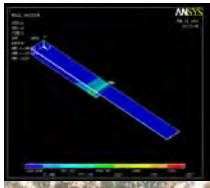




UAB offers short courses, workshops and a certificate in Composites based on a 6-sequence course offering. The course structure is flexible and can be tailored for different needs. The courses can be offered in a classroom setting or as web-based depending upon the needs of the industry.

C1. INTRODUCTION TO COMPOSITE MATERIALS
- Metals versus composites
- Fibers
- Polymers/Resins
- Foams and Honeycomb cores
- Interface
- Material forms (GMT, SMC, LFTs)
- Fabrics (2D, 3D, woven, braids, tapes)

C2. DESIGN & ANALYSIS OF COMPOSITES
Metals versus composites designs
Stress-strain behavior
Finite element analysis (Shells, Solids)
Continuous and discontinuous composites
Design of Sandwich Composites
Ribs, holes, cut-outs
Strain rate sensitivity
Mechanical joints and adhesives

C3. COMPOSITES MANUFACTURING
Thermoset versus thermoset composites
Thermoset composite processes
RTM, VARTM, SRIM, RRIM
Autoclave molding, Automated tape placement,
Filament winding
Compression molding, Thermoforming
Long fiber thermoplastics / Extrusion-compression molding
Pultrusion

C6. TEST METHODS
ASTM, MIL Standards & ISO methods
Static and Dynamic test methods
Static tension, compression, flexure, interlaminar shear failure
In-plane and out of plane tension & shear
Fatigue testing
Vibration testing
Impact test methods – Low velocity, intermediate and high velocity impact

C5. APPLICATIONS DEVELOPMENT
Integrated process and product development
Tooling and Process implications
Costing for Composites Products
Material selection
Structure-property relationships
Design, analysis and development for Defense and Transportation applications

C4. NONDESTRUCTIVE EVALUATION & QUALITY INSPECTION
Probability of defects
Process and service induced damage
Visual inspection of composites
Optical inspection methods
Ultrasonic inspection
X-ray radiography
Vibration testing
Acoustic impact

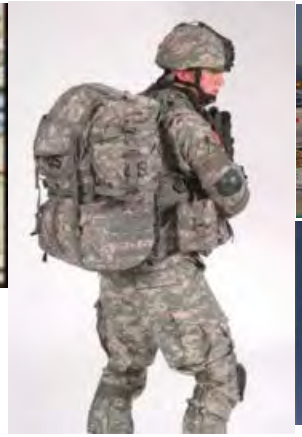
C7. COMPOSITE MECHANICS
Micromechanics & macromechanics
Rule of mixtures
Weight to volume conversions
Elastic moduli predictions for uni, bi- and multi-directional laminates
Strength predictions for uni, bi- and multi-directional laminates
Strength and elastic moduli of discontinuous composites

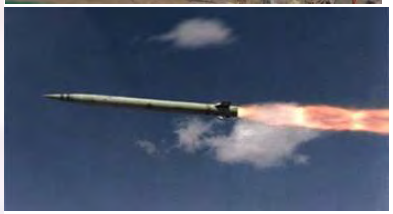
2010 Alabama Composites Conference at UAB - Focal area included Energy Efficient Transportation – ~350 participants attended

Expanding Avenues – STRUCTURAL COMPOSITES APPLICATIONS IN DEFENSE, TRANSPORTATION, POWER INDUSTRY, ENERGY & INFRASTRUCTURE

August 24-26, 2010

University of Alabama at Birmingham (UAB) Campus, Birmingham, Alabama





- High quality technical sessions, keynotes speakers and panel discussion.
- Technical sessions on transportation, defense, power & energy sector and infrastructure applications/technology transitions/commercialization
- Manufacturing, Design, Testing and Quality Inspection
- Information exchange & network opportunities for practicing composite engineers, small businesses, national laboratories & academic institutions.
- Exhibits featuring composite fabricators, material suppliers, product developers & end-users
- Workshop on *Corrosion Prevention* featuring structural composites – gain CEU credits
- Workshop on *Composites Design, Manufacturing and Testing* – CEU credits
- Opportunities for industry to meet potential hires - students who have training in areas of composite materials and manufacturing technologies
- Emerging technologies - student posters
- CD-ROM proceedings of technical papers and presentations
- A unique and high technical value meeting of its kind in the Southeastern United States

BIOCOMPOSITES FOR TRANSPORTATION (AUGUST 23rd 2010)

Automotive and transportation sectors are shifting to a 'green' outlook as manufacturers are increasingly introducing environmentally friendly structural and functional themes to their design.

The August workshop featured 23rd August 2010 for the Biocomposites International Network (BIRN) talks – covering state of the art in natural fiber composites. Speakers from US, Canada, Australia, South Africa and New Zealand presented at this meeting.

Presentation theme covered natural fibers, biocomposites and bioresins..

The GATE researchers were educated in the utilization of green materials in their thinking in terms of engineering design, processing and integration for technology insertion.

GATE Outreach (Summer 2010-Spring 2011)

- GATE research featured at Alabama Composites Conference, August 23-26, 2010 (~ 40 student posters featured GATE research).
- The Biocomposites International Network (BIRN) featured several speakers at the August workshop.
- Birmingham Southern College (BSC) – Zachary James Richards and Melanie Ann-Short(2 college seniors) spent 1 month (Jan 2011) at UAB GATE center and gained experience in foam compounding processes and trials
- Joshua Green (Holy Family Christo Rey High School) and Jamel Walters (Ramsey High School) spent Summer 2010 at UAB GATE center and were trained in processing and testing of composites. Both are underrepresented underserved community students/schools
- 12 students from Science and Technology Honors program at UAB were trained at the UAB GATE center in Composites Processing and Testing
- Short workshops for Alabama Nano Bio Science Academy for Teachers Follow-On Meeting at UA with Researchers – Web broadcast / Virtual classroom (UAB, UA, UAH) – 35+ teachers across these institutions
- BioNano Sustainability Consortium – REU/REH (July 29, 2010) – 15 students
- Alabama Boys State Group – Mini-workshop (July 08, 2010) – 18 students
- Southern Company sponsored Middle School Girls student group (ICAN-Girls in Engineering) (Jan 2, 2011)– Mini-workshop 35 students
- Engineering Academy Students, Hoover, Alabama.- Cuyoha, Valley Christian Academy, Akron, Ohio exchange program(GM mentorship) – Mini-workshop at UAB GATE center (Jan 15, 2011) – 11 students
- Freshman Engineering Training (EGR 200) – Lightweight materials design, processing and validation – 56 students (Spring 2011) – 8 class session, Mini-workshop includes design and build
- GATE faculty are advising Baja Racing Vehicle and Wind Energy related projects in materials by design relationships (~20 students affected)

GATE workshops contd…

Data analysis with JMP statistical discovery software workshop

Mia Stevens, Connie Freeman, SAS Institute, Oct 7, 2010, (30+ students, 15+ faculty and researchers attended

SPE Automotive Composites Consortium (SPE ACCE), Sep 2010 Poster session organized and administered by GATE faculty, Troy, Michigan (Sep 2010)

Characterization for static and dynamic properties – tensile, compression, flexure, interlaminar shear, static indentation, low velocity and high velocity impact was offered again (Held October 25-26, 2010).

LS-DYNA and Hypermesh modeling for automotive FEA., Haibin Ning (Held November 16-30, 2010, 6 sessions)

Session organizer on Biocomposites at International Conference on Composite Materials (ICCM 18), 2011, Jeju, South Korea (premier conference on composite materials - over 2000 attendees expected)

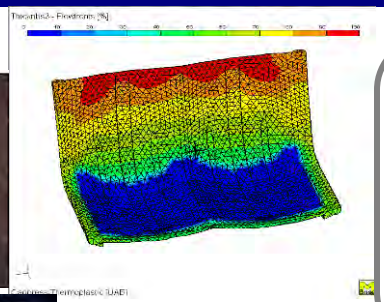
Notable speakers and visitors

- Ahmed Vakili., Univ of Tennessee Space Insitute, Pitch Based Carbon Fibers – March 2011
- Michael Wyzoski., Long Fiber Fatigue Predicitive Modeling, American Chemical Council – March 2011
- Ganesh Deka., Low Cost High Production Rate Carbon Fiber Preforms, Neenah Fibers, April 2011.
- Mark Janney., Recycled Carbon Fiber from Aircraft Waste for Transportation, Materials Innovation Technologies, August 2010
- USMBI – Mercedez Benz International, Vance, Alabama (Team of Lead Engineers for BIW, Interior, Paint etc. led by CEO Markus Schaeffer) Dec 2010.
- Daimler Trucks, America – Lead Engineer, Mark Locitelli, Jan 2011.
- Kirk Atkinson, Bremen Investment and Uwe Daller, Daimler Procurement, Dec 2010
- Nemac Steel, Hannah Steel, Raymond Monroe American Steel Council members, Aug and Dec 2010.

GATE Leverage to New Programs

- National Science Foundation – Recycled Thermoplastic Composite Microballoons for Transportation., Sioux Manufacturing
- DOE Phase III – Recycled Carbon Fiber for Mass Transit Transportation., Collaboration with Materials Innovation Technologies (MIT)
- Large Reinforced Molding (LRM) – Highway Noise Barrier Panels – Acoustics Testing and Characterization

Technical Accomplishments



Basic science.
Design, analysis
and applications
For energy efficient
lightweight material

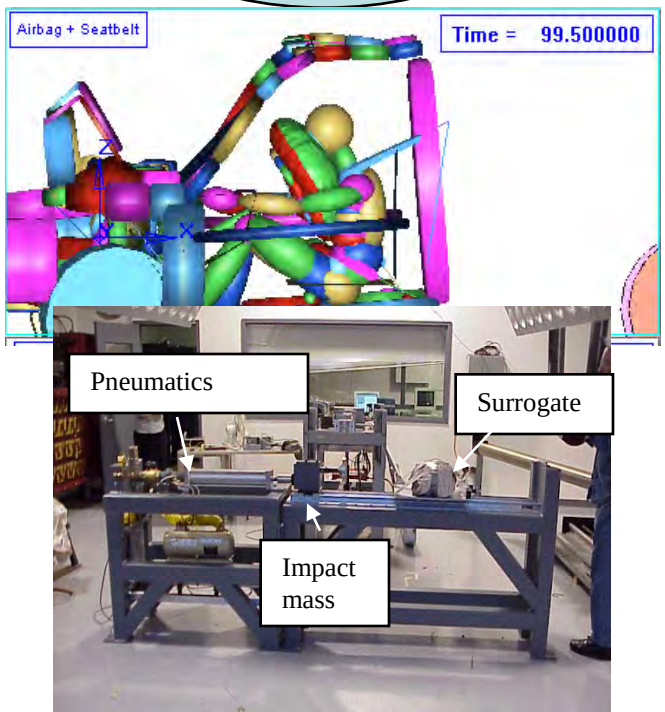
Advanced Composites Technologies

Advanced Metal Casting Technologies

Automotive castings

Advanced materials for automotive safety

High fidelity computations for crashworthiness studies

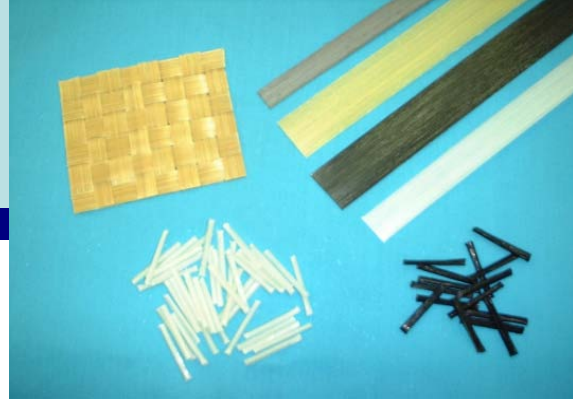


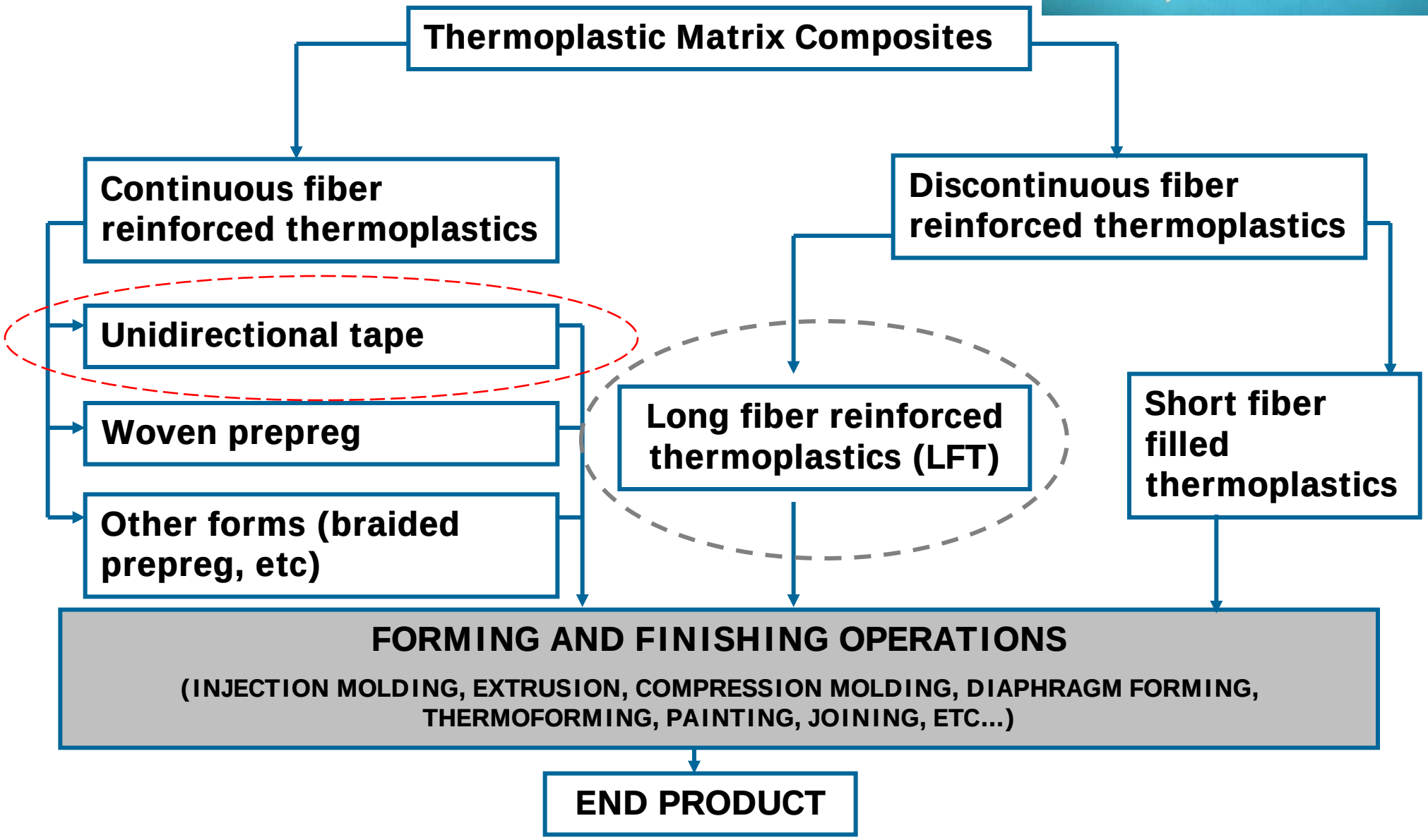
Lightweight materials for highway safety

Technical Accomplishments

- 40%-60% weight reduction, and ~40% cost-savings featuring energy-efficient composites in DOE relevant mass transit and automotive applications (examples included).
- Carbon fiber impregnation with thermoplastic polymers research expanded.
- Integration of natural fiber composites and nanostructured biocomposites development for vehicle applications
- Advances in crashworthy materials – compounded thermoplastic foams
- Strong industry collaboration with GATE research aligned with US industry base and strong DOE relevance.
- Technical publications (see list) by GATE fellows in – long fiber rheology, natural fiber composites, biomechanics/ crashworthiness, fiber/matrix interface studies, multifunctional materials, real time X-ray for castings inspection, innovation in process methods
- Lost foam casting developed to minimize material porosity
- Advances made in thermoplastic extrusion-compression, pultrusion and forming techniques applicable to materials for safe highway barriers and energy-efficient automotive structures

Materials Forms for Thermoplastic Composites Manufacturing





UAB GATE added a Twin screw compounding facility in Fall 2011

- Leistritz Micro 18 Twin Screw Extruder
- Co-rotating screws
- Screw Diameter (D): 17.8 mm
- Screw Functionary Length: 40D
- No. of Heating Zones: 7
- No. of Cooling Zones: 6

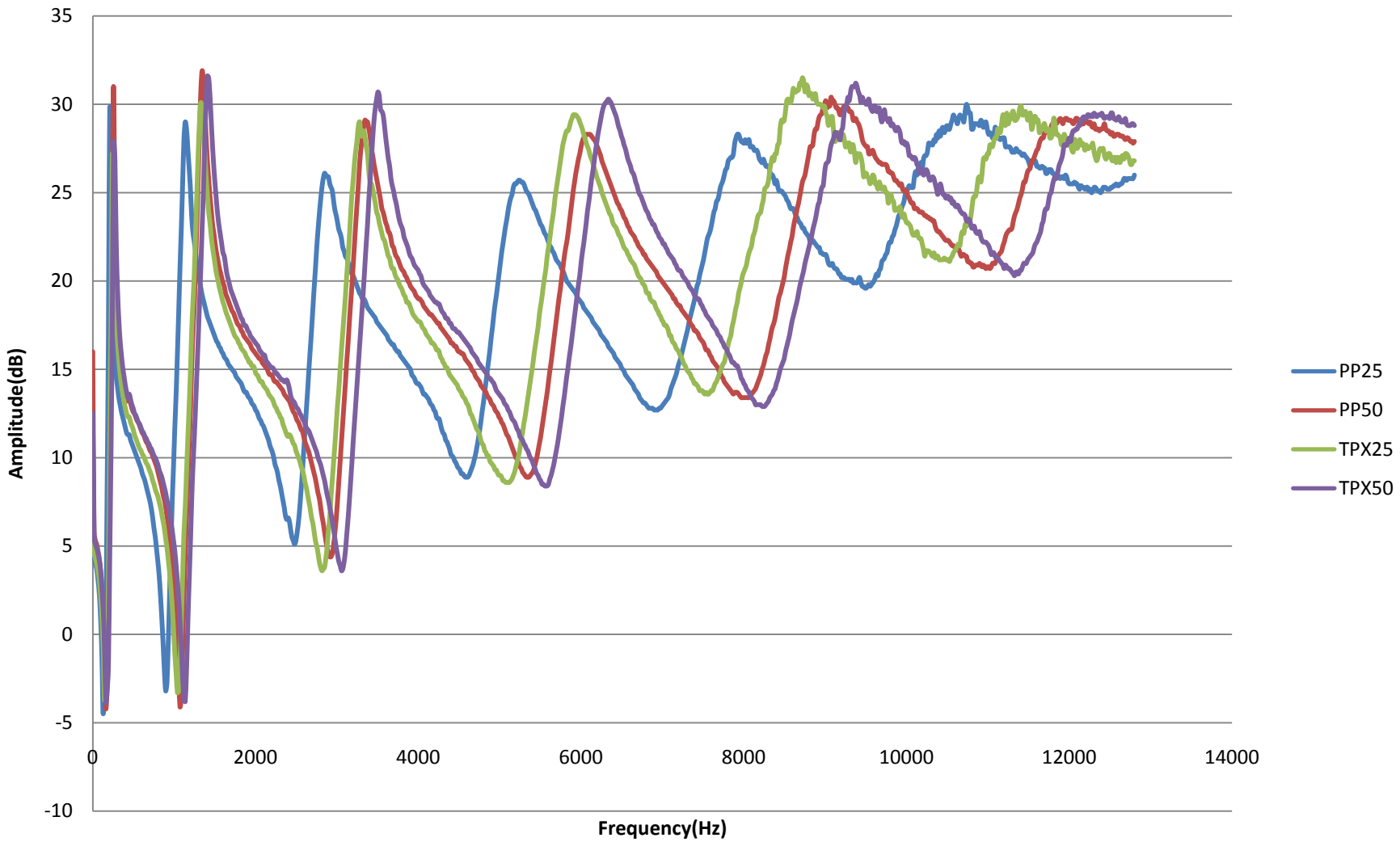
Crammer & Micro
Spheres Feeder

Compounded Material
Exiting Die

Water Bath for
Cooling

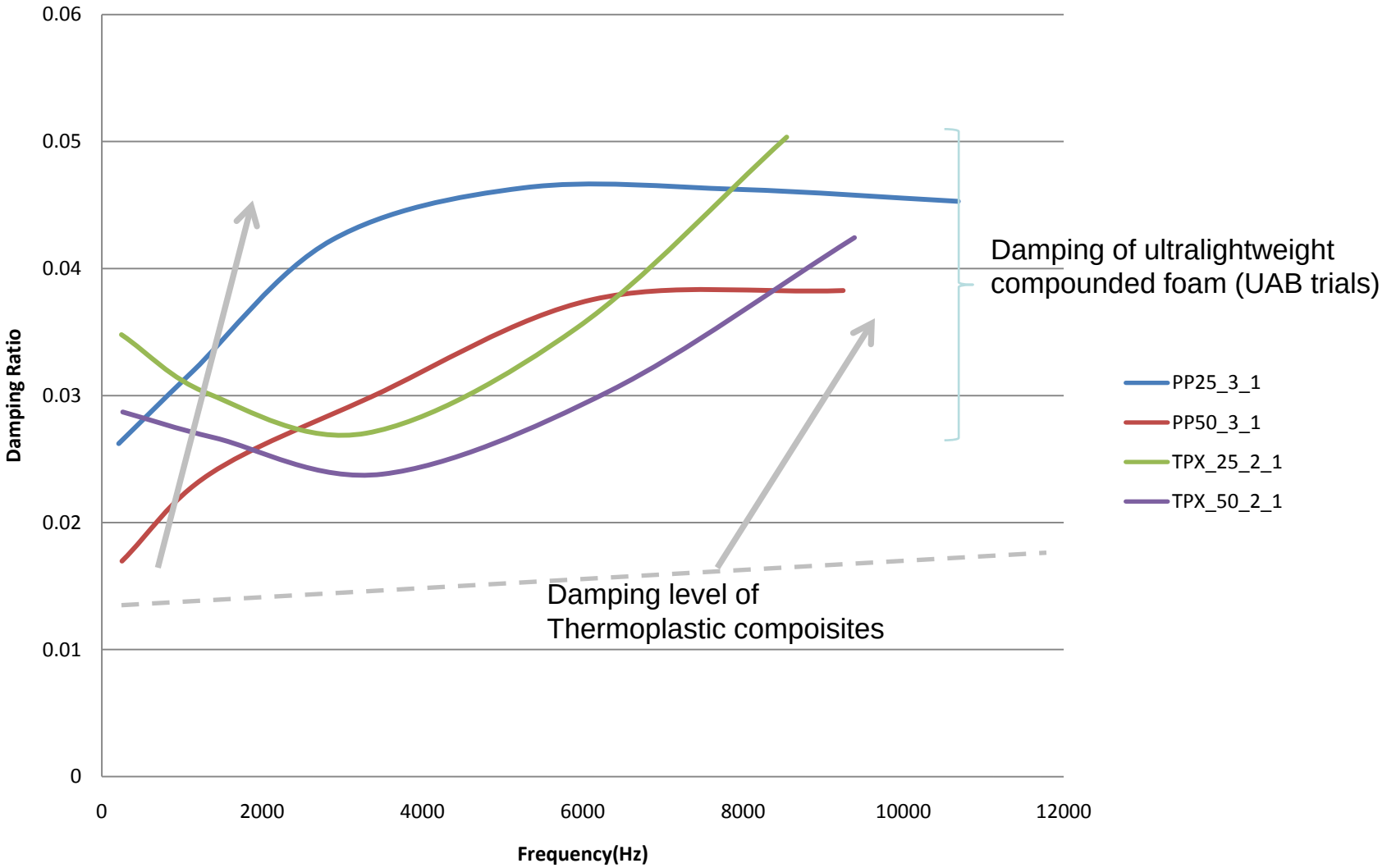
Davis-Standard
WARNING
Puller & Pelletizer

Vibration Frequency Response of foam-polymer beams



The representative frequency response show very similar vibration response between the various beams.

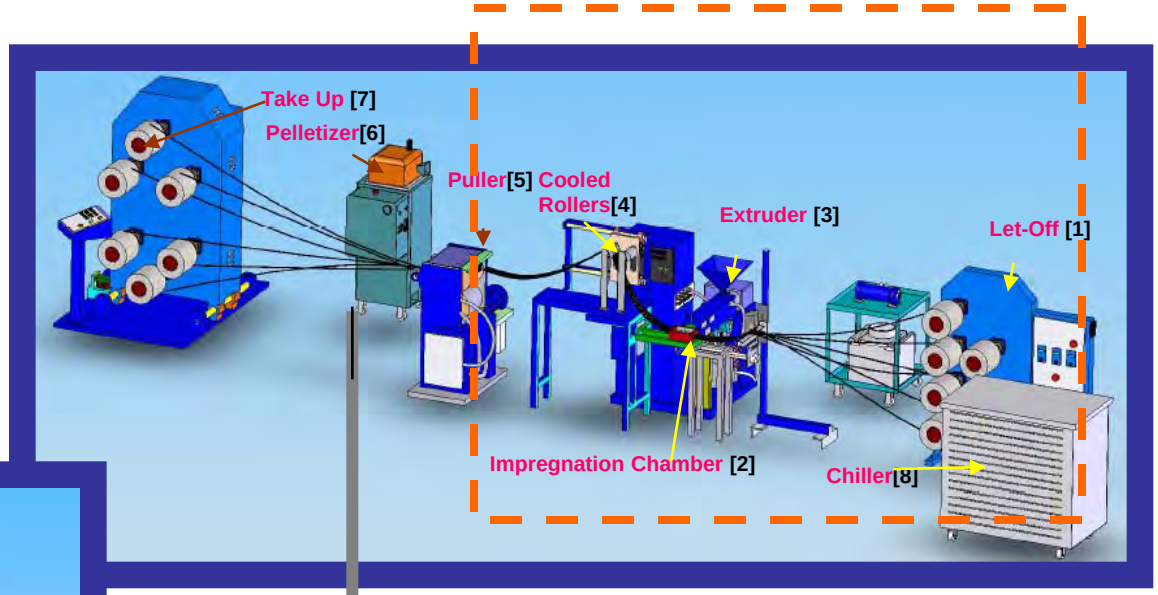
Damping enhancement possibilities by ultra lightweight compounded foam

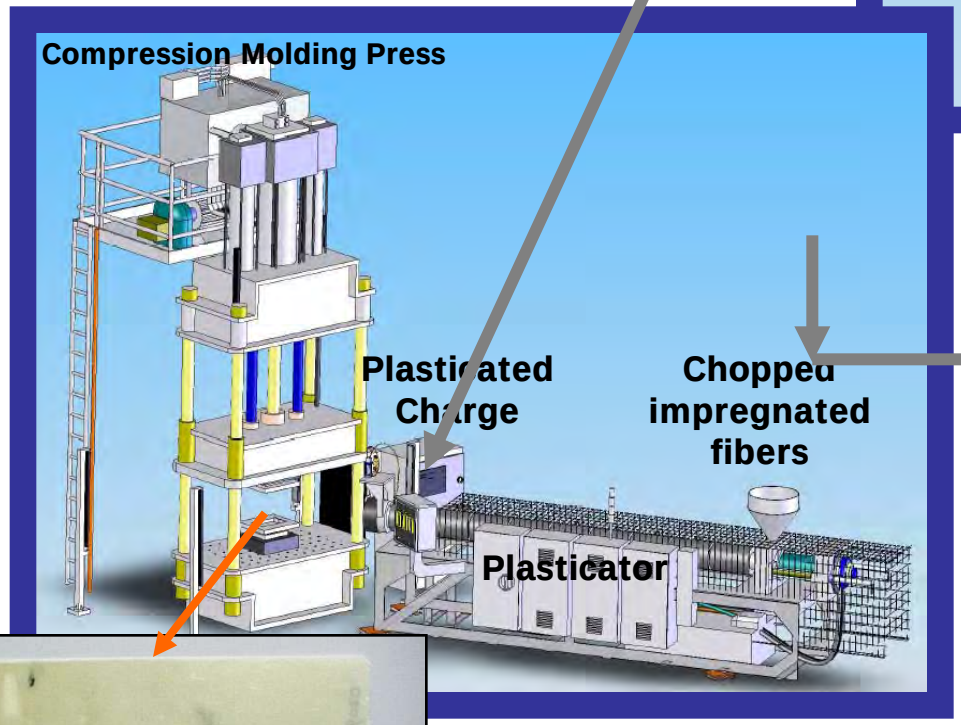


Significant enhancement of damping capacity by the compounded foam materials. While we are in the process of quantifying between the variants, all variants show multifold increase in damping, therefore promise for enhanced crashworthiness in automotive applications

Hot Melt Impregnation & Extrusion-Compression Molding (Several news applications were developed)

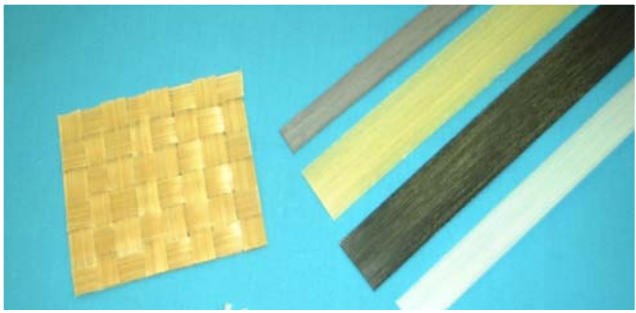
Charge / Shot

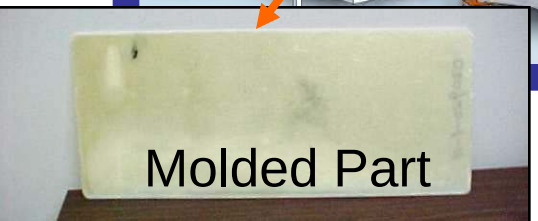




LFT Pellets

Tape & Fabric



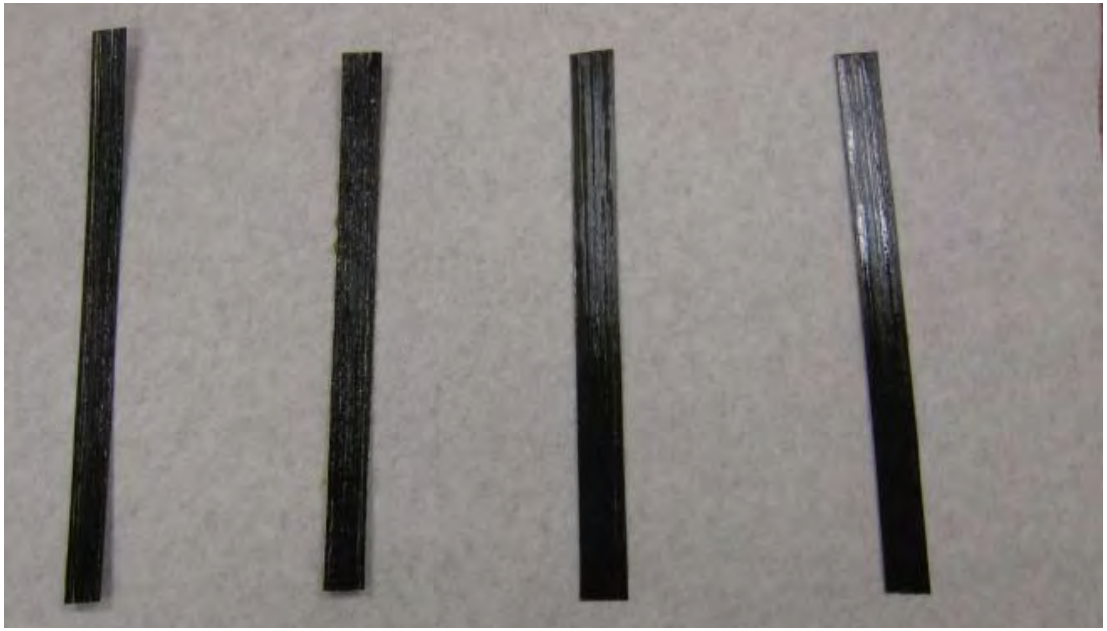


Molded Part

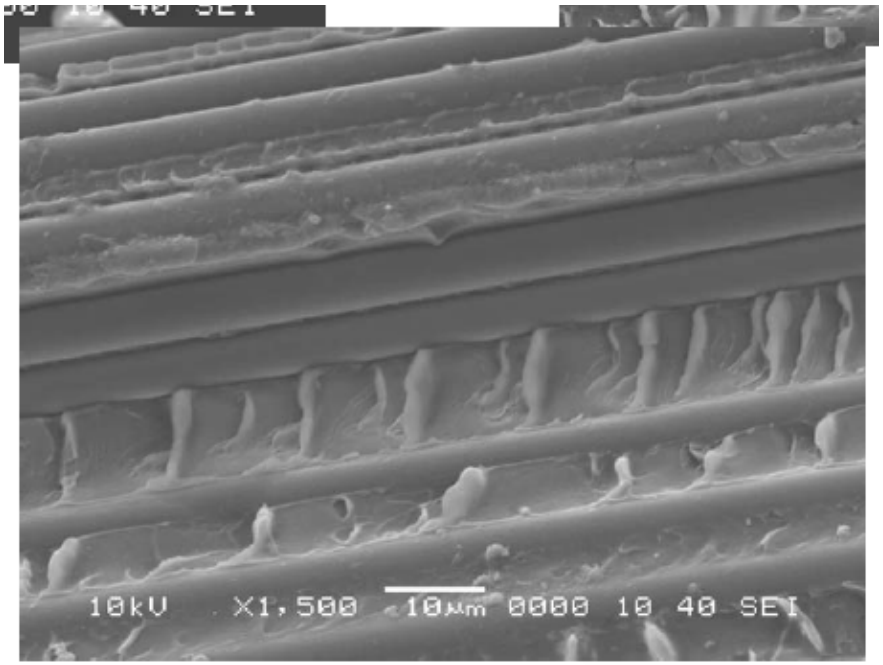
Carbon Fiber Thermoplastic Impregnation Studies

- Carbon fiber has promise for significant weight reduction in vehicles provided cost can be reduced.
- There are very limited carbon fiber sizing options for thermoplastic polymers.
- Carbon fiber sizing is generally proprietary from industry.
- Work has been initiated by GATE fellows to impregnate PAN and textile grade carbon fiber with thermoplastic polymers (Work aligned & coordinated for DOE ORNL interest based on discussions with Dave Warren & Bob Norris, ORNL)
- Successfully impregnated Polypropylene and Polyamide thermoplastics on carbon fibers sized for epoxy, vinyl ester and unsized PAN fibers in Summer 2009. Impregnation quality is excellent; physical, static & dynamic mechanical property evaluations are underway.
- In October-Nov 2009; we have successfully impregnated carbon fiber with poly ether imide resin (see next slide).
- These material options can be used by the automotive and transportation industry in number of broad good applications for exterior and interior structural panels.

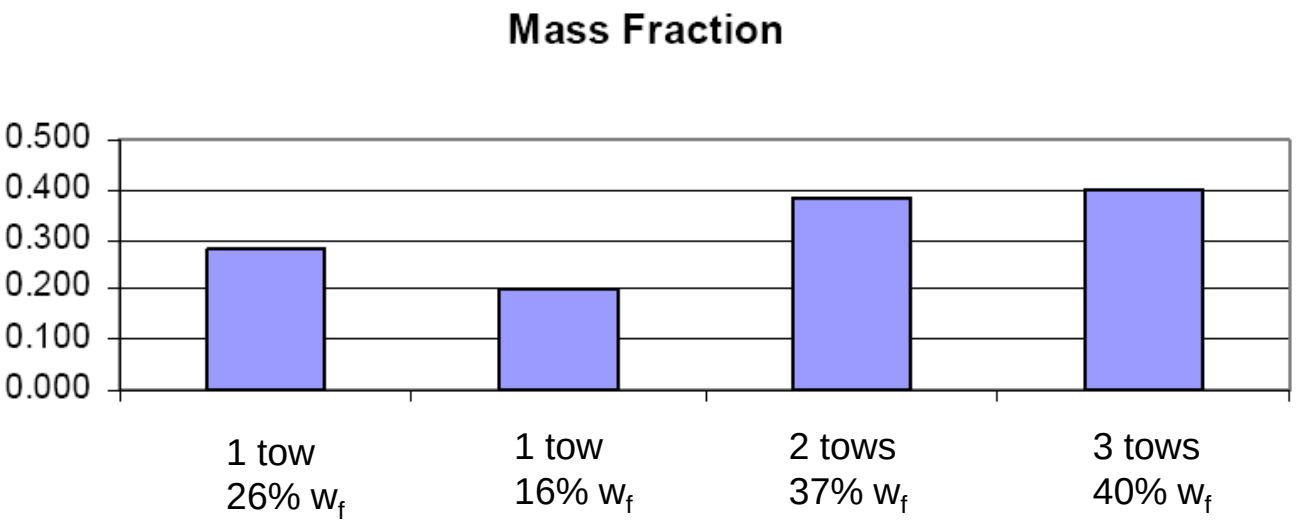
Carbon Fiber Thermoplastic Polymer Impregnation Studies (Ongoing work…)



1 tow 26% w_f | 1 tow 16% w_f | 2 tows 37% w_f | 3 tows 40% w_f



SEM: Wet-out of PEI to PAN carbon fiber tape

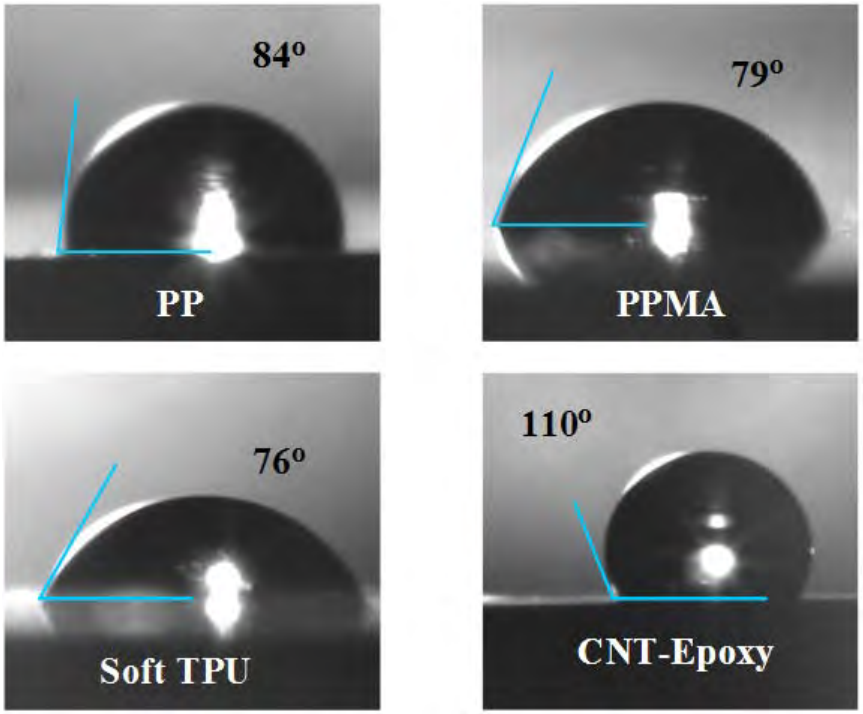


1, 2 and 3 PAN carbon fiber tows were subjected to hot-melt impregnation with poly ether imide resin. The viscosity of the resin poses a challenge for processing. Tapes up to 40% w_f were successfully produced.

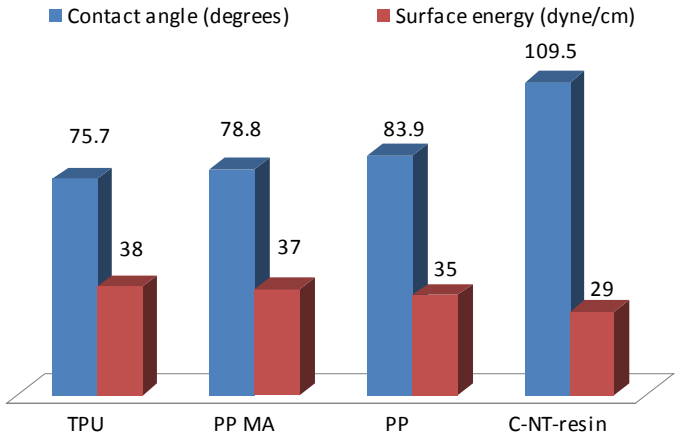
Mechanisms of Interfacial Adhesion in Metal-Polymer Composites

DOE Merit Review
May 2011

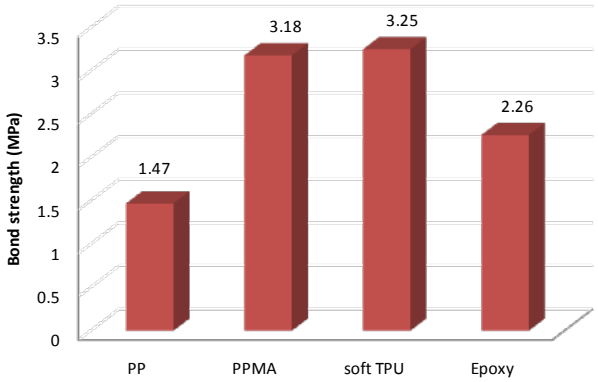
This study investigates the chemical interaction between steel and thermoplastic polymer by reactive adhesives and chemical treatment of surfaces. Adhesion between polymers and steel has been studied by chemical surface treatment. Modification of the surface to create greater surface area, in addition to imparting free radical surface effects to create new surface bonds with introduced chemical functionalities, are the primary approaches for maximizing interfacial adhesion. Plasma activated chemical vapor deposition (PACVD) is used to impart silicon, carbon and hydrogen radicals to the metal surface.



Droplets of distillated water on polymer surfaces for measuring contact angle



Contact angle and surface energy for different polymer types.



Effect of polymer type on the bond strength at the polymer-steel interface.

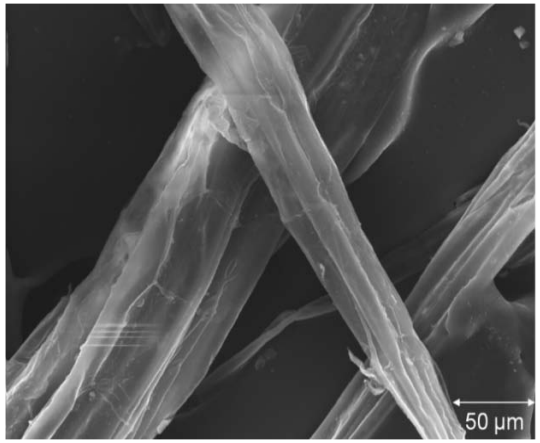
Ochoa & Vaidya., Composites Part A; Applied Science & Manufacturing, In-print

Banana Fiber Composites Development
Students: Nsianda Mfala (UG-G), Theresa Bayush (UG)

DOE Merit Review
May 2011

The use of natural fiber reinforcement or fillers yields lower **carbon footprint** materials with mechanical properties suitable for the automotive, transportation, construction and furniture industries.

- Natural fibers present some challenges:
  - High Moisture uptake
  - Low thermal stability
  - Low bonding with polymers
- Chemical treatments can improve the fiber performance.
- The effect of a chemical treatment with NaOH solutions on the properties of natural fibers and the resultant composites are being studied.



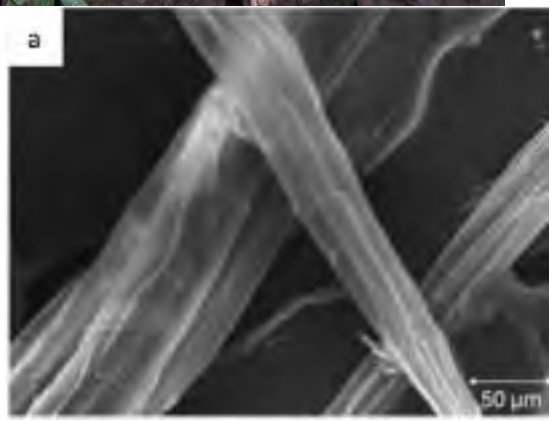
- Banana fibers appear as smooth filaments.
- Waxes cover the surface of the fiber.
- There is few fibril protrusion.

Natural Fiber Composites & Nanostructured Biocomposites for Vehicles

- Fibers obtained from the dried stalk of banana trees.
- These fibers are a waste product of banana cultivation.
  - Sodium Hydroxide (NaOH) treatment:

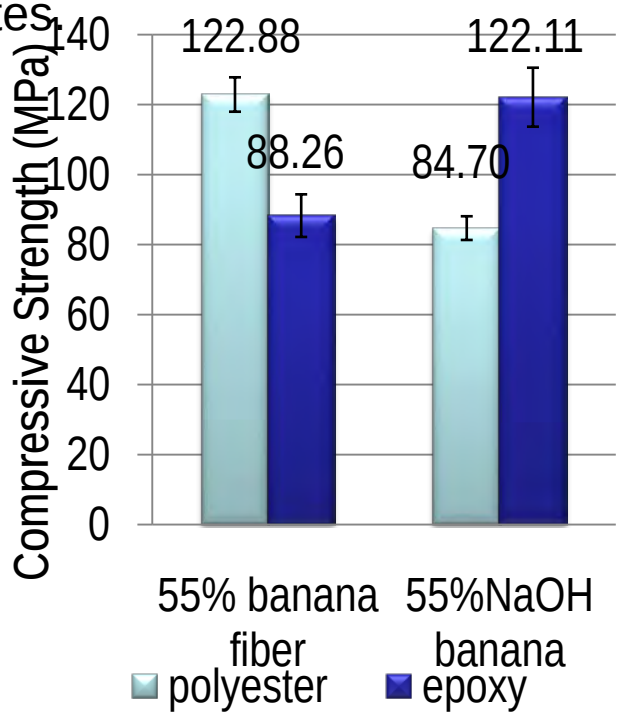
    Removes impurities from the fiber surface, Decreases moisture absorption, causes mechanical bonding and alters surface polarity

Alkali treatment enhances fiber/matrix interaction, causing a decrease in moisture absorption and higher compressive strength in banana fiber/epoxy composites



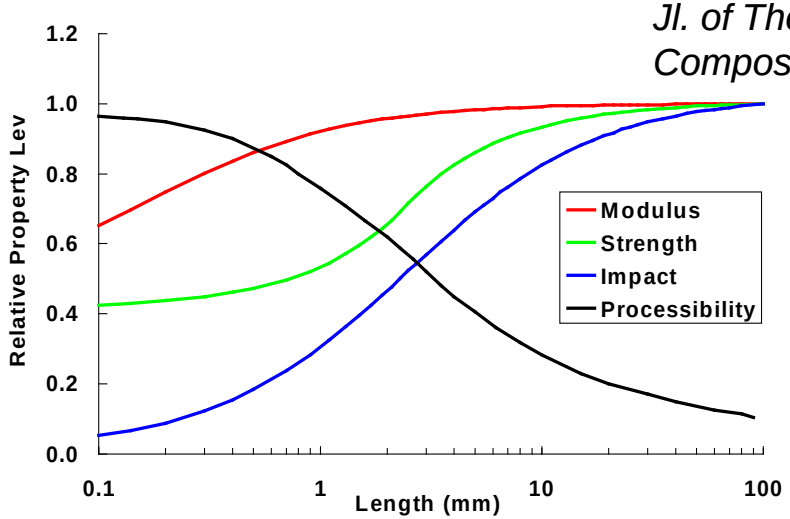
As-received

NaOH treated

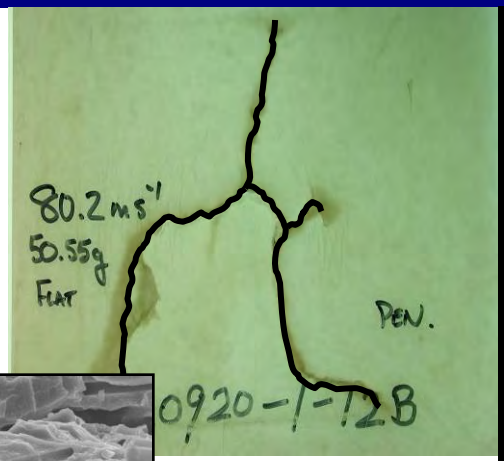


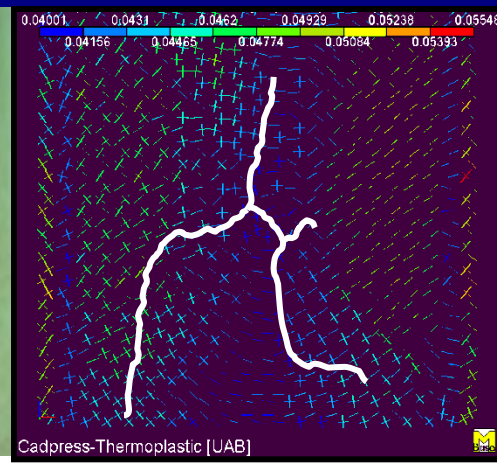
Other examples of Basic Research by GATE fellows

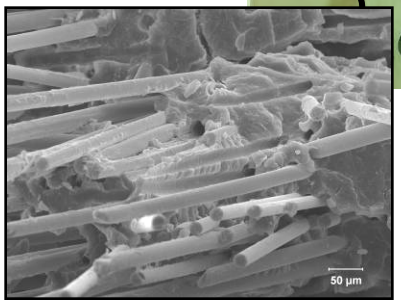
Jl. of Thermoplastic Composites, Sep 2008



Performance and processability windows for advanced thermoplastics composites

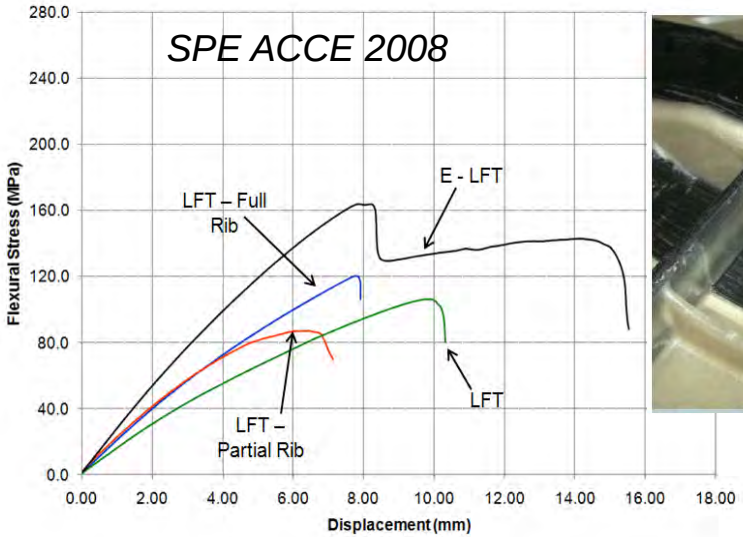






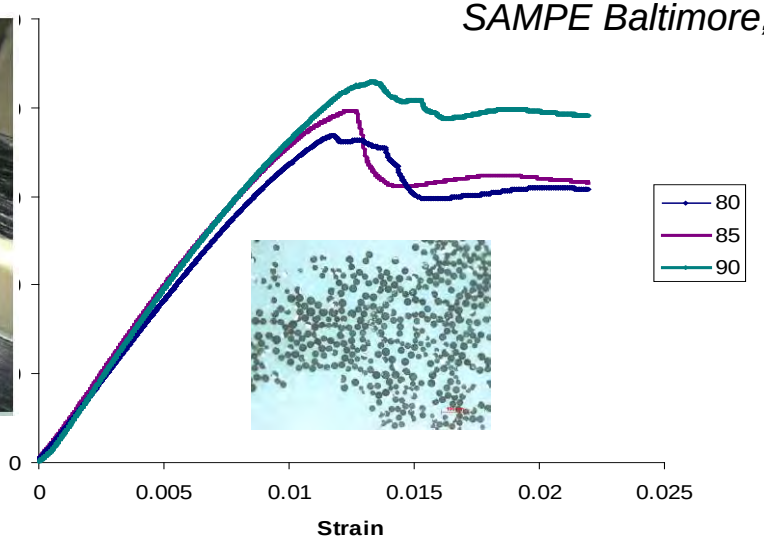
Impact /microstructure/modeling Correlations of long fiber thermoplastics

SPE ACCE 2008



Studies with co-molded continuous tape and long fiber thermoplastics for enhanced energy absorption and crashworthiness, improved safety

SAMPE Baltimore, 2008

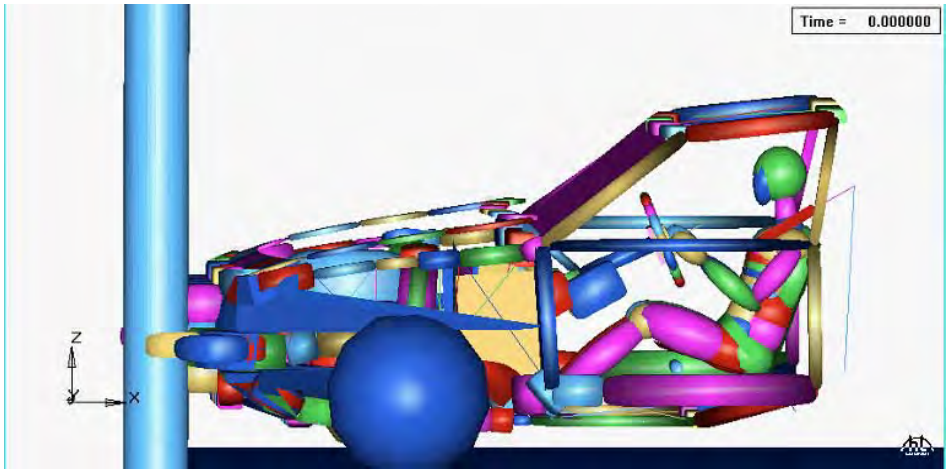


Thermoplastic pultrusion process optimization of materials profiles used in structurally efficient members for transportation

Crash modeling and Injury Biomechanics

Multi-Body Dynamics

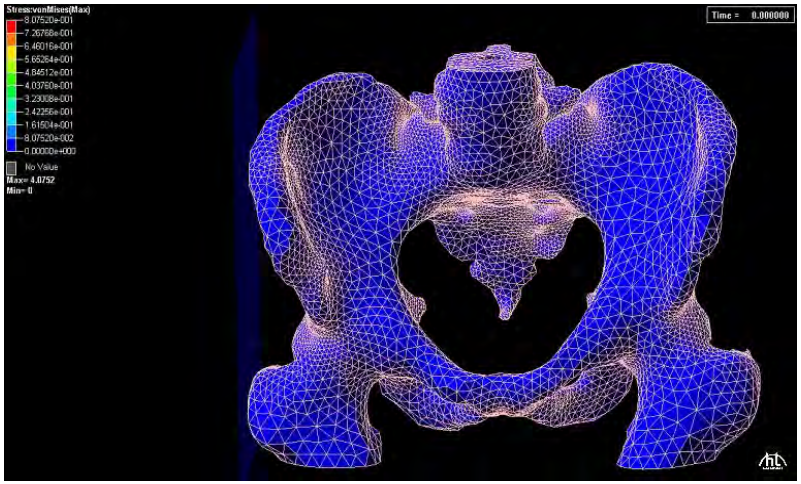
- Multi-body system comprised of rigid and/or flexible bodies
  - Joined together by kinematic joints
  - Acted on by forces
  - Systematic and efficient algorithms for governing equations of motion
- Commercial codes : MADYMO, ADAMS, DADS, etc.



MADYMO simulation :
A vehicle with dummy impact to a pole

Finite Element Methods

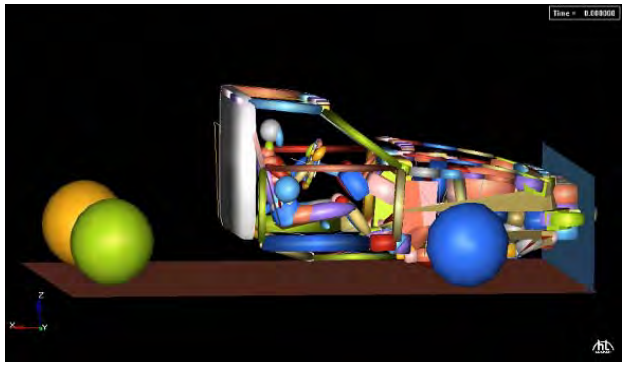
- Can be applied to all of engineering fields
  - Dynamic solution of structural system
  - Solve governing equilibrium equation for finite element discretized in space
  - A variety of material constitutive models
- Commercial codes : LS-DYNA, PAM-CRASH , RADIOSS, etc.



LS-DYNA simulation :
Side impact of a human pelvis

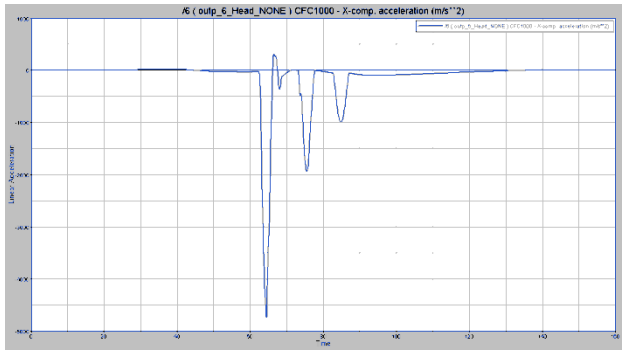
Multibody Analysis

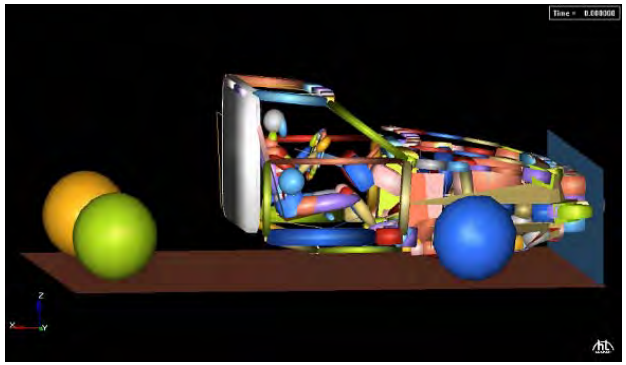
Case study to examine the effect of occupant restraint system on brain injury level, 5th percentile female dummy,, FMVSS (Federal Motor Vehicle Safety Standards) 208 regulation (30 mph initial velocity, impact to full front rigid barrier)



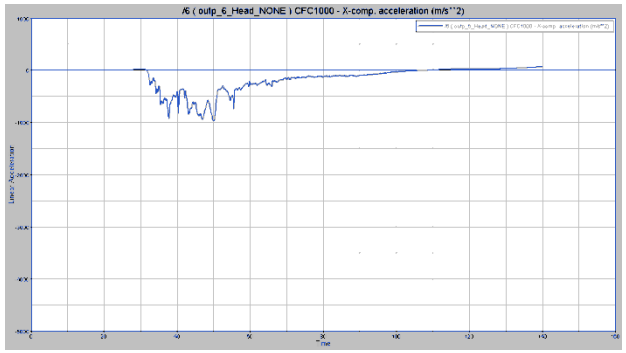
Extract head deceleration data at center of gravity in the principal direction of force

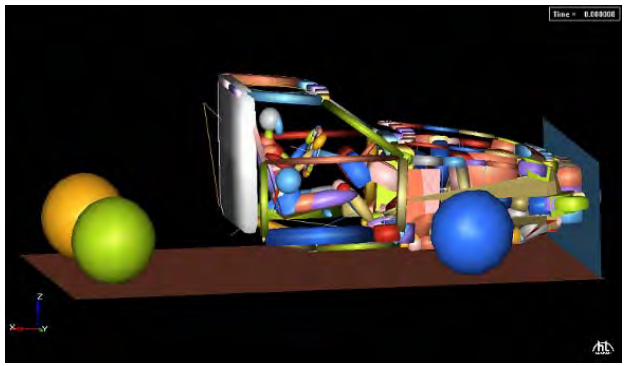
No airbag
No seatbelt
(NR)



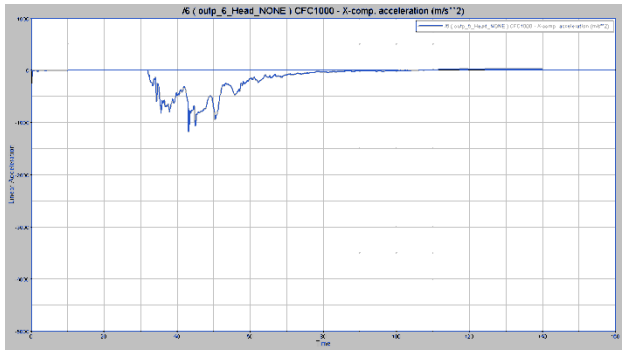


Airbag
No seatbelt
(UB)





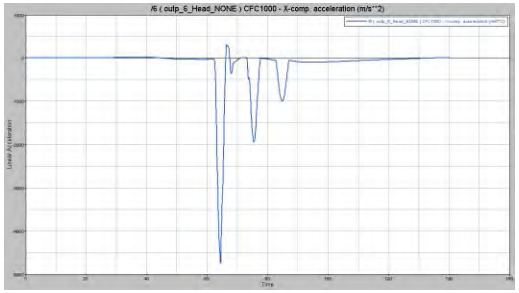
Airbag
Seatbelt
(BT)



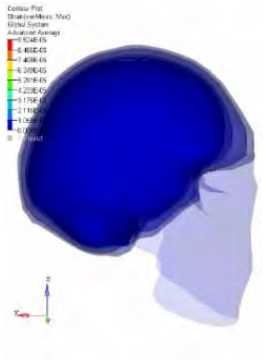
Finite Element analysis to evaluate head injuries

Analysis using LS-DYNA

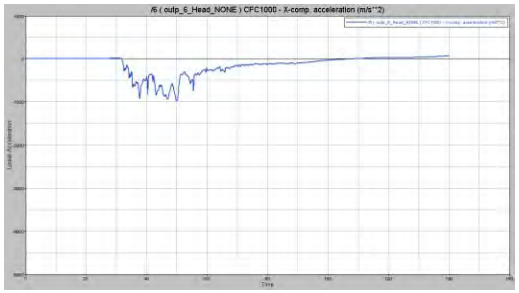
From deceleration data from Step 1

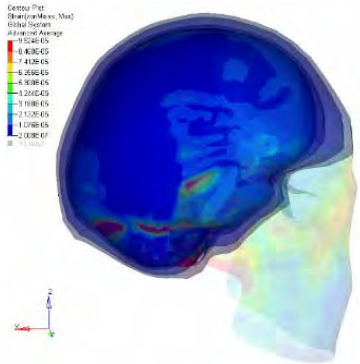


- **Apply initial velocity (30 mph)**
- **Apply head deceleration data from Step 1 by a LS-DYAN option, "Boundary_prescribed_motion"**

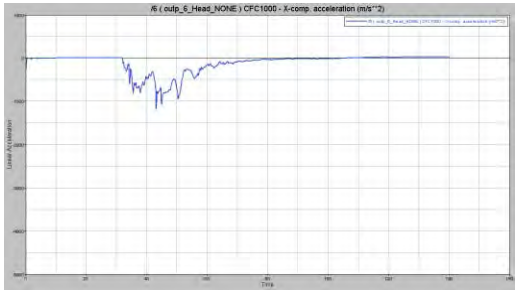


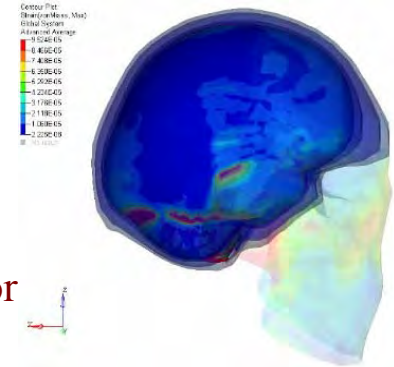
No airbag
No seatbelt
(NR)





Airbag
No seatbelt
(UB)





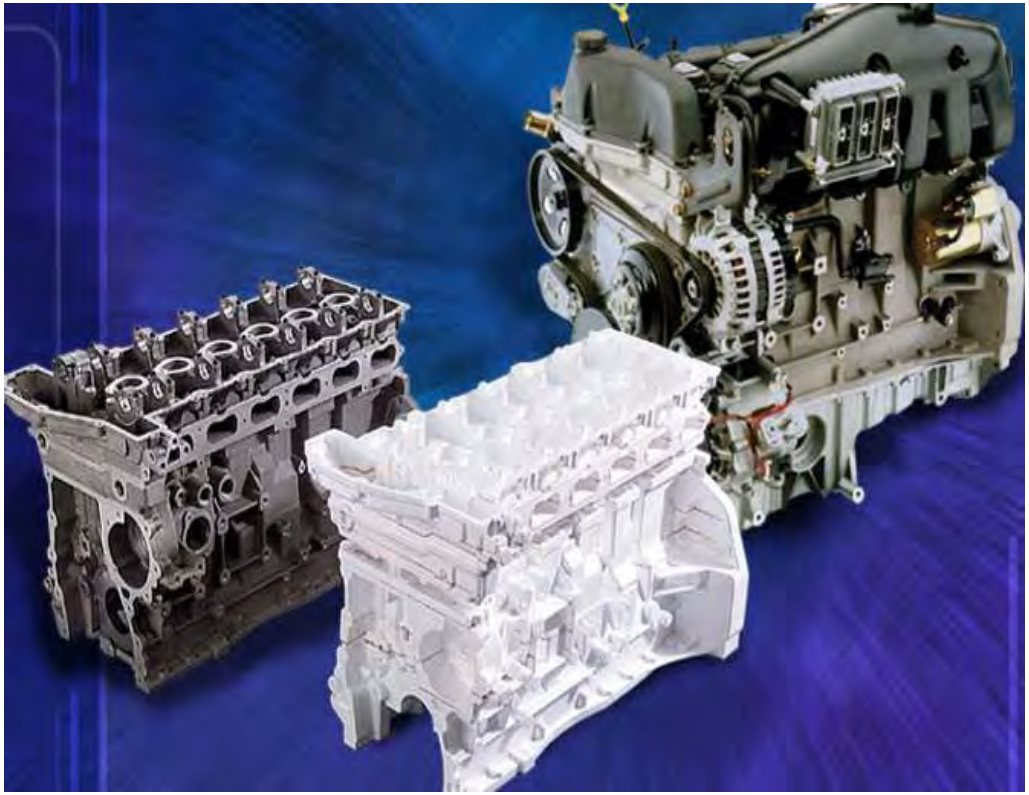
Airbag
Seatbelt
(BT)

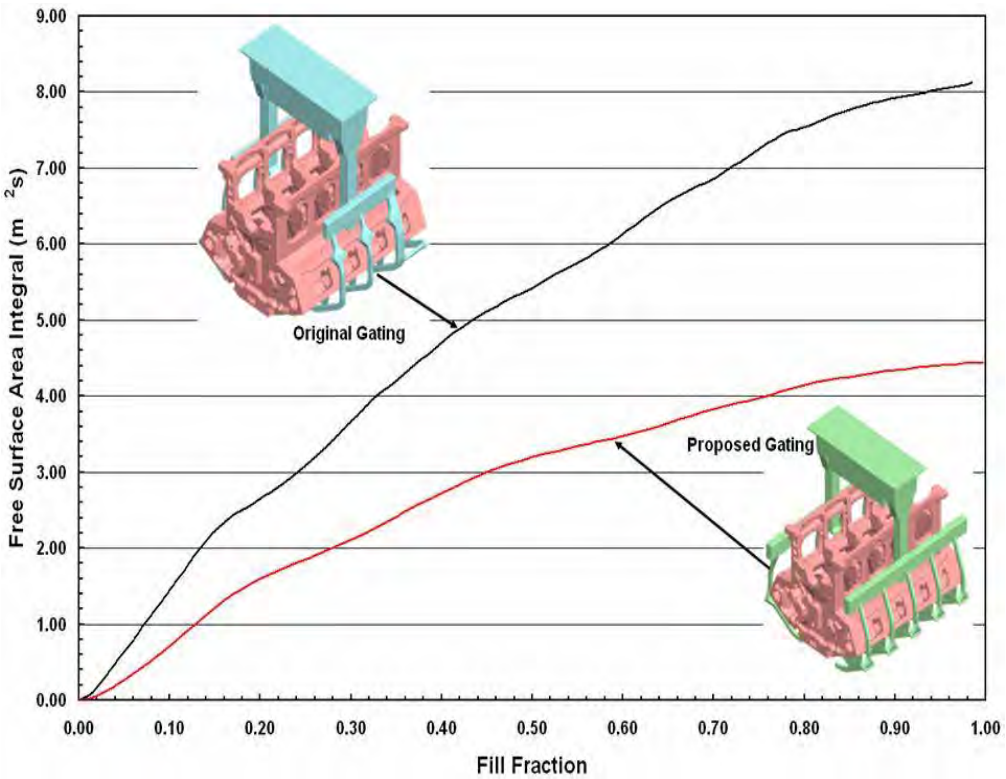
* Consider dummy's head deceleration only in the principal direction of for

* No rotational acceleration/deceleration were considered

Aluminum Castings for Automotive Applications

UAB has an international reputation for expertise in the evaporative pattern (lost foam) metals casting process. Federal funding and industrial partners are supporting research in complex aluminum castings

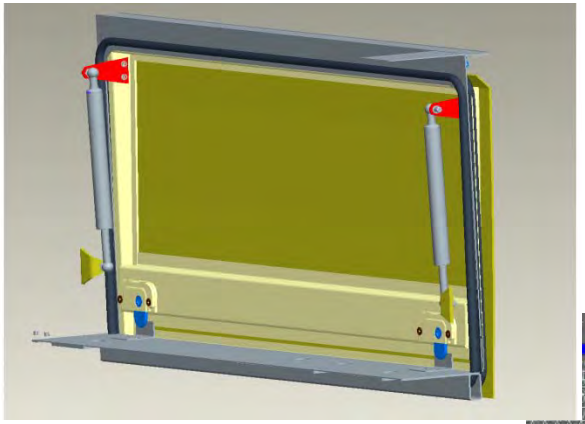




Modeling of flow during mold filling for engine block castings has led to a 45% reduction in casting defects.

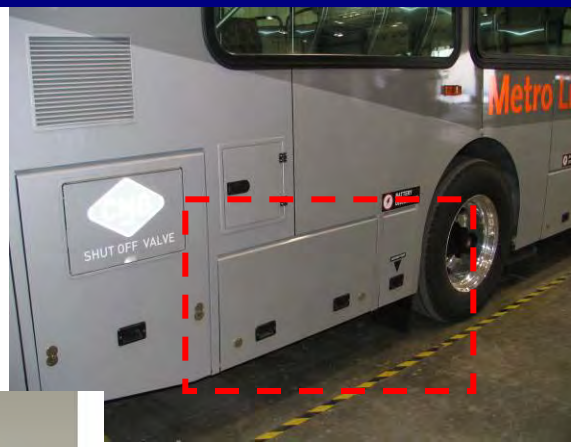
Thermoplastic Composite Materials for Transportation Applications

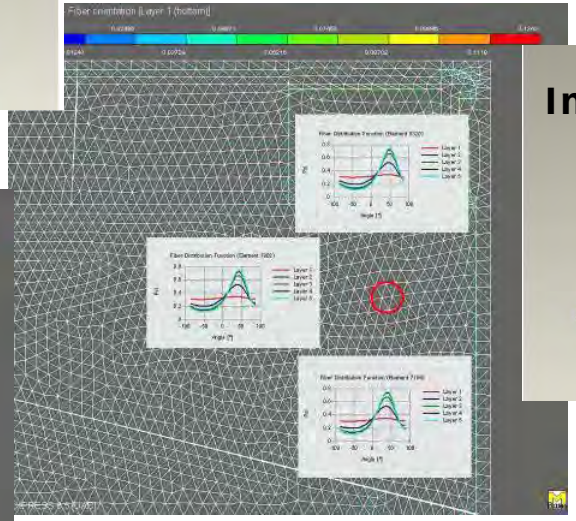
DOE Merit Review
May 2011

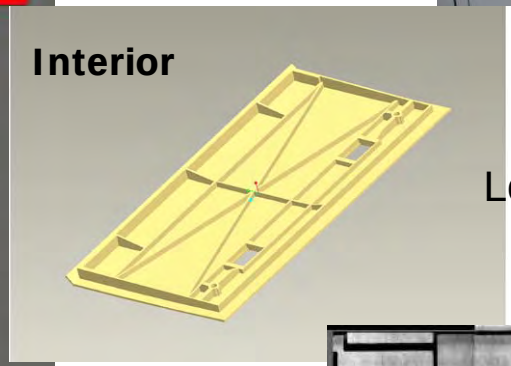


Heavy metal door

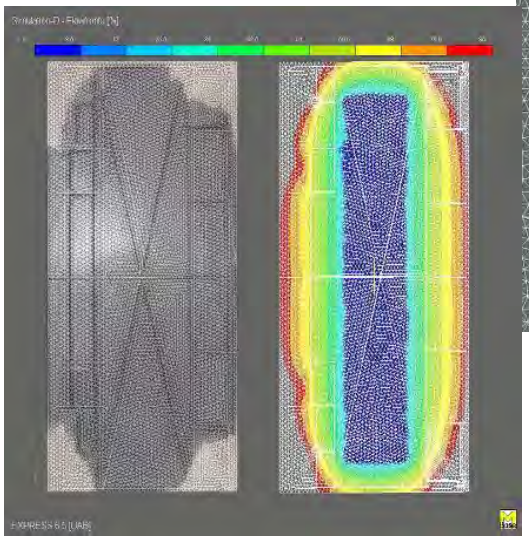
60% weight reduction & 40% cost-savings realized by replacement of metal battery door by long fiber composite







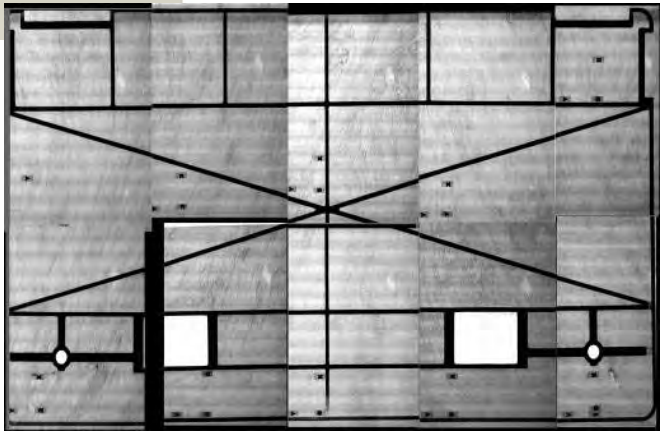
Long fiber thermoplastic door; 60% lighter



Process flow modeling of long fiber charge

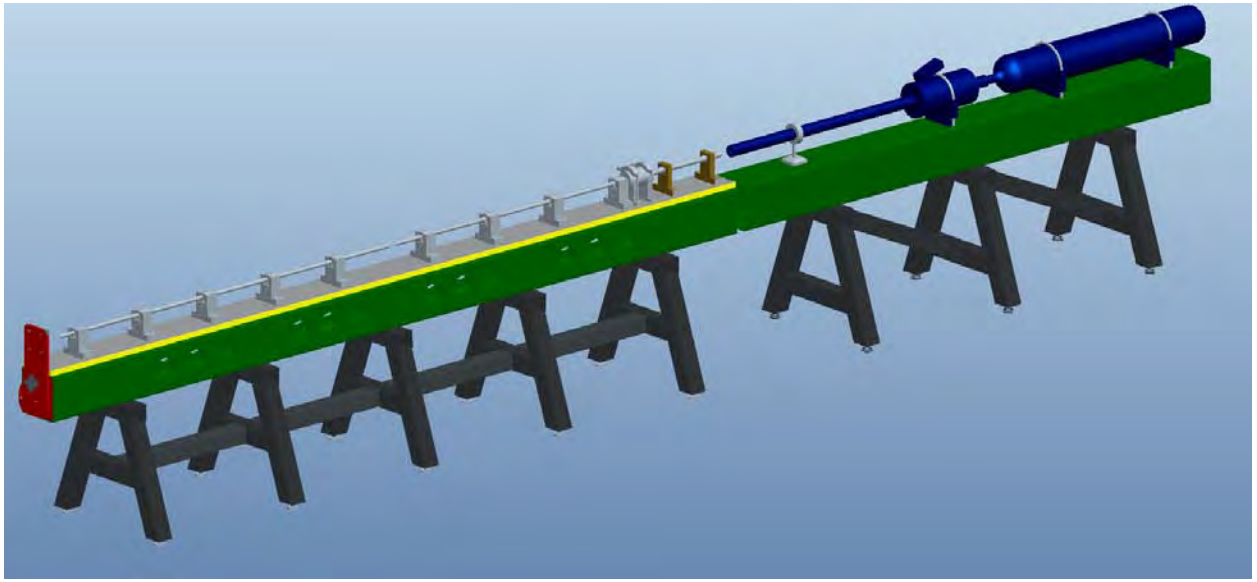
Fiber orientation modeling and prediction

- ☑ IP disclosure filed
- ☑ Technology transfer
- ☑ NABI and other mass transit companies interested in implementation



X-Ray studies to evaluate fiber orientation

Balaji T et al., Process simulation, design and manufacturing of a long fiber thermoplastic composite for mass transit application., Composites Part A: Applied Science and Manufacturing, Volume 39, Issue 9, September 2008, Pages 1512-1521



Design and Construction of Hopkinson Pressure Bar for Crashworthiness Training

A split Hopkinson pressure bar is the benchmark testing method to perform high strain rate compression testing of materials to evaluate their crashworthiness.. At high rates of strain, mechanical properties change drastically. Properties such as yield strength, work hardening, and ductility are completely different when examined at these levels.

GATE scholars have designed and built a SHPB at UAB GATE to evaluate high strain rate properties of lightweight metals and steels. This data will be extremely helpful for modelers to input design data for materials behavior of stress-strain as a function of strain rate (strain rate sensitivity).

Car and Driver “One Lap of America”

- GATE students develop carbon fiber parts for Honda of America (HOA)
- HOA races the ***Honda Odyssey*** in the ***One Lap of America*** competition.

Honda PILOT : 2009-2010

Body in-white (Honda of America, Lincoln, Alabama plant)

GATE senior design students – Zack Snyder, Rosemary Sacris, John McKinney and Hadeel Abdelmajeed

Honda Pilot Carbon Fiber Roof

GATE students have fabricated a carbon fiber sandwich composite roof for the *Honda Pilot*. 40% lighter than metallic one presently used.

Previous work with Honda of America – UAB GATE students developed the Carbon Fiber Hood for the Honda Odyssey Van

Carbon Fiber Hood assembled weight – 8 lbs

The metal hood weighs – 28 lbs

Carbon Fiber Hood Development

GATE students Hadeel Abdejmajeed, Danila Kaliberov, Walter Malone, K. Balaji & Michael Magrini working on the carbon fiber hood fabrication

The race was May 2-10, 2008. Placed 26th overall out of approximately 80 teams; first in the SUV class.

Interactions with DOE Oak Ridge National Laboratory (ORNL)

- Visits to ORNL – Meeting with Dave Warren to discuss carbon fiber lightweighting research
- Student exchange under ORISE and Oak Ridge University User Agreements
- Southeastern Automotive Alliance Consortium – UAB partner with Oak Ridge and National Transportation Research Center (NTRC)
- Utilization of high rate testing capability at Oak Ridge for material property evaluation at high strain rates
- Process modeling of composite materials
- GATE advisory board members from ORNL& invited speaker – Dave Warren, ORNL

Partial List of Publications and Presentations (2010-2011)

- Vaidya U.K et al., Application Development with Thermoplastic Composites for Automotive and Mass Transit, Invited Talk, ICC-CFT 2011, Indian Institute of Science, Bangalore, India, Jan 4-7, 2011.
- Carol Ochoa and U.K.Vaidya., Interfacial Shear Strength in a Metal-Thermoplastic Composite, Polymers and Polymer Composites., Vol. 18, No. 7, pp. 369-380, 2010.
- Carol Ochoa and U.K.Vaidya., Mechanisms of Interfacial Adhesion In Metal-Polymer Composites. Composites Science and Technology Journal (Accepted, In-press).
- U.K.Vaidya, Balaji, T, S. Pillay, H. Ning., Colored Inorganic Pigmented Long Fiber Reinforced Thermoplastics., SAMPE Seattle, May 2010.
- U.K.Vaidya, Balaji Thattai, D.Kaliberov, S. Pillay and H. Ning., Recycled Long Fiber Thermoplastic Composites for Transportation Applications. SAMPE Seattle, May 2010.
- John Smith and U.K.Vaidya, Progressive forming of thermoplastic composite laminates., SPE Automotive Composites Conference & Exposition (ACCE 2010), Troy, MI, Sep 15-16, 2010, CD-ROM proceedings.
- Nanostructured banana fibers/biopolymer composites for transportation., Nsiande Mfala and Theresa Bayush., SPE Automotive Composites Conference & Exposition (ACCE 2010), Troy, MI, Sep 15-16, 2010, CD-ROM proceedings.
- Utilization of heavy truck industry scrap for production of long fiber thermoplastic recycled composites for use in transportation., Ameya V. and Balaji T., Auburn University, SPE Automotive Composites Conference & Exposition (ACCE 2010), Troy, MI, Sep 15-16, 2010, CD-ROM proceedings.

Technology Transfer/Collaborations

Companies Funding Research Relevant to the GATE Program

#	Collaboration	Interaction
1	Britt Engineering, AL	Fire Suppression - Automotive Floors
2	National Composite Center, OH	Prototyping, Virtual Manufacturing
3	Shepherd Color Co., OH	Functional Inorganic Paints
4	Glasforms, AL	Thermoplastic Pultrusion for Transportation
5	Ticona Inc.	Long Fiber & Thermoplastic Materials
6	Milliken (Tegris)	PP fibers/PP matrix for Body Panels
7	Trelleborg of Boston (TOB)	Syntactic foam microballoons
8	Materials Innovation Technologies (MIT)	Recycled carbon fiber for transportation

Partners for Workshops and Guidance

#	Collaboration	Interaction
1	Lawson State Community College, AL	2-year college/Student Pipeline / Workshops
2	Miles College, AL	HBCU/MI college; Student Pipeline / Workshops
3	Rhodes College, Memphis	Work Force Development / Workshops
4	Milwaukee School of Engineering, WI	Strong Pool of BS Graduates / Workshops
5	Calhoun Community College, Decatur, AL	Student Pipeline/ Workshops
6	Oak Ridge National Laboratory, TN	Guidance & Program Relevance

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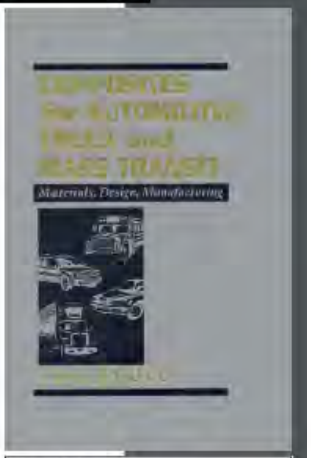

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Summary of Progress towards GATE Goals and Objectives

- ✓ Support 3 graduate students/year - 16 *graduate students have been supported to date by GATE funds (3+ years)*
- ✓ Support 4 undergraduates each year – 21 *undergraduates have been supported to date*
- ✓ Develop and offer two new automotive related courses per year to impact 20 to 30 students per year – *7 GATE courses have been developed with a total enrollment of 130 students; several courses have been offered at least twice*
- ✓ Influence at least 30 students per year through hands-on workshops – *to date 300+ students have participated in the GATE Workshops*
- ✓ Interact with industry through Advisory Board meetings, tours of facilities, 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*

Overall Impact of UAB GATE 2005-2010

- ✓ 16 GATE scholars were funded (partially and some fully)
- ✓ 21 undergraduates were supported as graduate pipeline
- ✓ 7 GATE courses were developed with a total enrollment of 130 students
- ✓ Instituted GATE certificate for students taking at least 4 GATE courses – positively influenced employment opportunities for GATE scholars in automotive and related industries
- ✓ Expanded interaction with DOE labs – ORNL and Industries
- ✓ Over 300+ students participated in various GATE workshop offerings
- ✓ 100+ publications and conference presentations by GATE scholars and GATE faculty over 5 years
- ✓ Expanded relationships with OEMs and OEM suppliers
- ✓ UAB gained significant reputation as GATE center for excellence – helped tremendously in infrastructure development from non-DOE sources
- ✓ We estimate that for every $1 investment of GATE, there was a $10 return on investment
- ✓ GATE project helped leverage grants from NSF, Army and SBIR/STTR programs
- ✓ UAB is applying for a 5-year renewal to expand impact in low cost carbon fiber, biocomposites and application development for automotive to align with CAFÉ standards and medium/heavy truck