GATE Center of Excellence at UAB for Lightweight Materials and Manufacturing for Automotive Technologies

Uday Vaidya (Principal Investigator)
University of Alabama at Birmingham (UAB), Birmingham, Alabama

May 2012

www.uab.edu/composites

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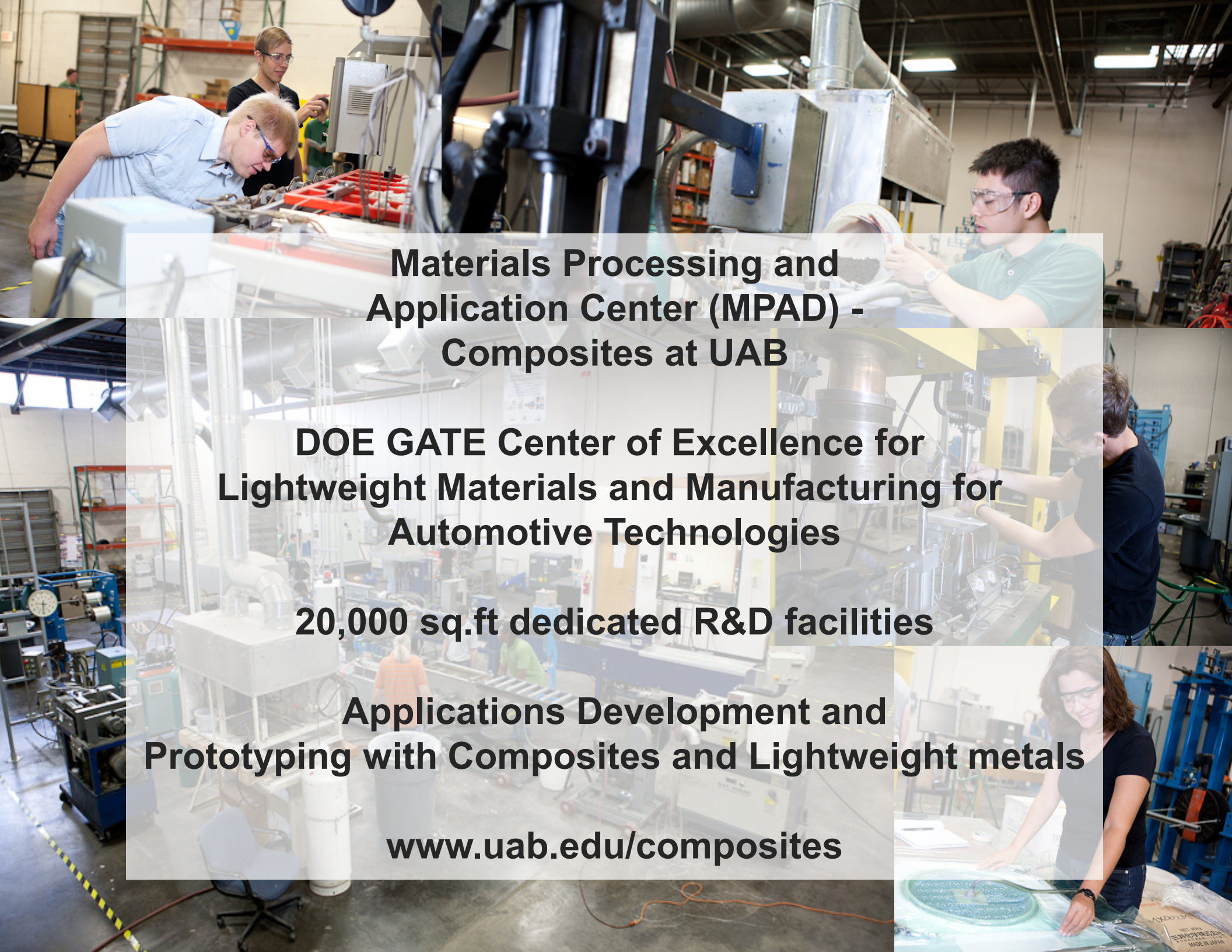
GATEWAY TO THE FUTURE
GATE
GRADUATE AUTOMOTIVE TECHNOLOGY EDUCATION

UAB

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 Lightweight Materials and Manufacturing for Automotive Technologies

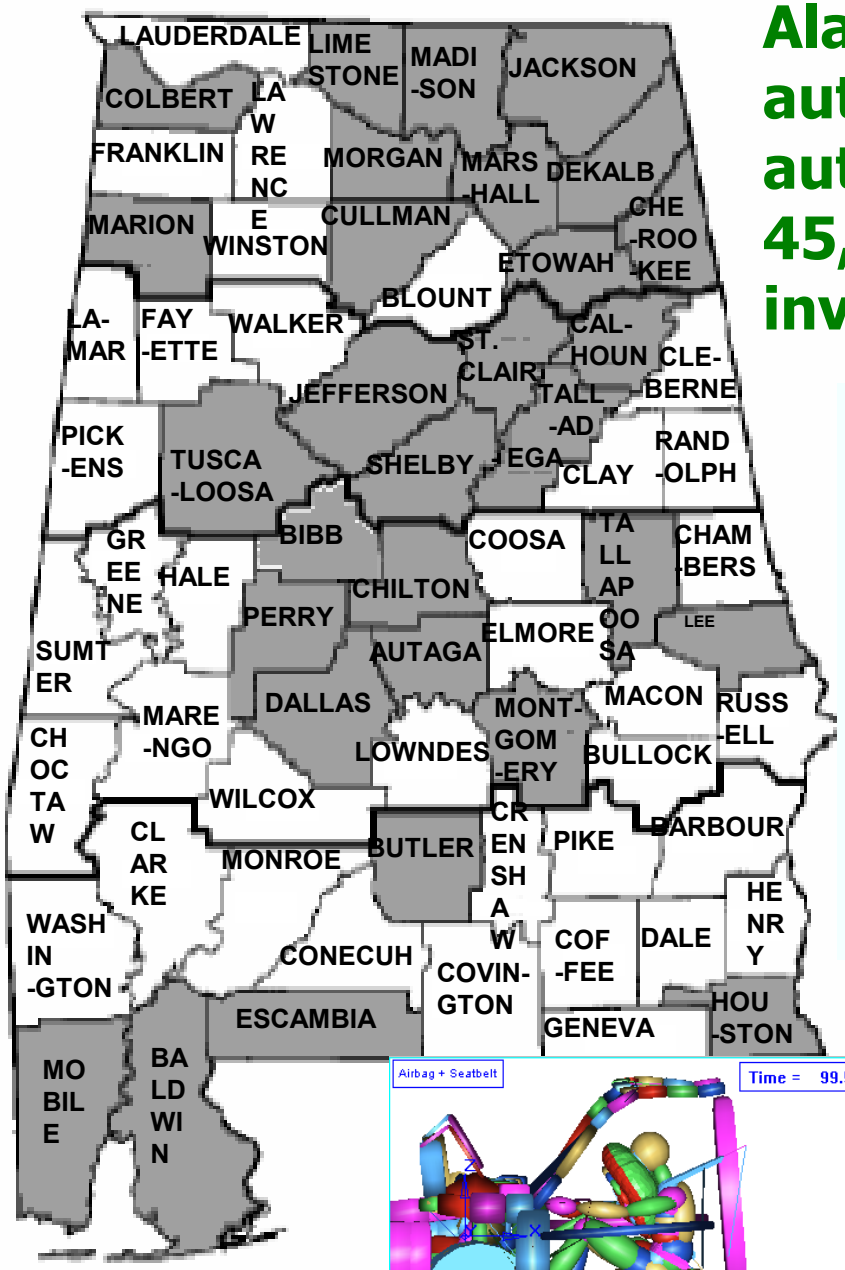
20,000 sq.ft dedicated R&D facilities

Applications Development and Prototyping with Composites and Lightweight metals

www.uab.edu/composites

Automotive Industry Impact in the State of Alabama

DOE Merit Review
May 2012



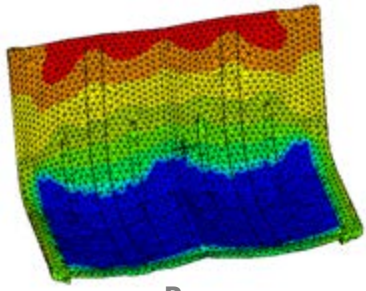
Alabama has a rapidly growing automotive industry. Since 1993 the automotive sector has created more than 45,000 new jobs and $8 billion in capital investment in Alabama.

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

DOE GATE Goal

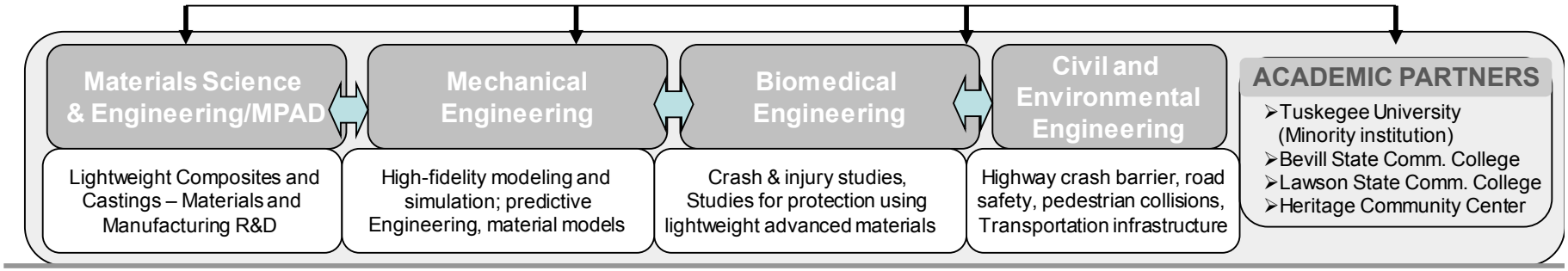
- **"To provide a new generation of engineers and scientists with knowledge and skills in advanced automotive technologies."**

The UAB GATE Goals are focused on the above FCVT,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.

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

DOE Merit Review
May 2012



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

UAB GATE Year 1 (2011-2012) Objectives

- Tailor GATE course offerings to accommodate GATE A and B series courses. Offer two courses each in the GATE A and B series that will enable graduate students across disciplines to pursue a GATE certificate option.
- Coordinate and offer three 2-day workshops for a total of 30 students from the collaborating institutions including the 2-year colleges, university, community center and industry partners.
- Recruit GATE students by selection, identify and begin interdisciplinary research projects
- Advisory board meeting
- Industry tour to at least 2 sites

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 (pipeline) in automotive related research
- Develop and offer 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

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

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, Sophomore	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 Courses – Fall 2011/Spring 2012

Fall 2011 GATE Courses

- Modeling and Simulation for Crashworthiness - Impact mechanics, finite element analysis, use of LS-DYNA and ANSYS software, case studies in material-body interactions, impact collisions modeling and analysis.(GATE faculty – Kim) – 15 students
- Mechanical Characterization and Performance Evaluation of Advanced Lightweight Materials – Mechanics of Deformation; Test methods including traditional static testing combined with dynamic impact, low, high strain-rate and high velocity blunt and sharp object (GATE faculty- Vaidya) – 9 students

SPRING 2012 Jan – May 2012 - GATE Courses (Currently in progress)

- Process Quality Engineering. Statistics and quality aspects of process engineering such six sigma, design of experiments and materials handing (GATE faculty – Pillay) – 10 students

- Nondestructive Evaluation. Principles, applications and limitation of ultrasonic, vibration, acoustic emission, radiographic, magnetic particle, eddy current and other nondestructive testing methods. Intelligent sensors and health monitoring of real structures (GATE faculty – Vaidya) – 9 students

- Predictive Engineering – Integrated Process Modeling and Design – Finite element analysis for automotive and transport applications (GATE faculty - Ning) -12 students

GATE course – Series A and B being developed as part of the 5-year plan

GATE A series courses*

(*Developed in the 2005-10 GATE period*)

- 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
- Nanomaterials for Automotive Applications.
- Process Quality Engineering
- Nondestructive Testing & Evaluation

GATE B series courses**

(*New courses*)

- 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. The GATE A and GATE B series courses and GATE certificate option will be make available to the industry participants as well.***

GATE Certificates

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 6 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 Review
May 2012

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)

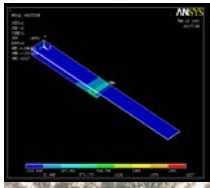
C2. DESIGN & ANALYSIS OF COMPOSITES
Metals versus composites designs
Stress-strain behavior
Finite element analysis (Shells, Solids)
Continuous and discontinuous composites
Design of Sandwich Composites
Ribs, holes, cut-outs
Strain rate sensitivity
Mechanical joints and adhesives

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

BIOCOMPOSITES Workshop (Planned for June 2012)

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

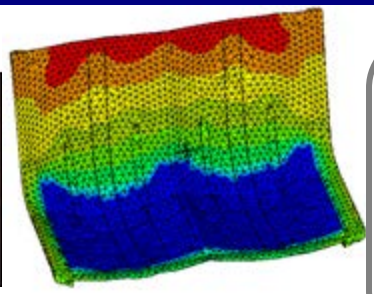
The June 2012 workshop will have presentations in natural fibers, biocomposites and bioresins – Lectures will be given by academic and industry experts

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

GATE Leverage with Industry and other Agencies

- National Science Foundation – Recycled Thermoplastic Composite Microballoons for Transportation., Sioux Manufacturing – Phase II SBIR
- DOE Phase III – Recycled Carbon Fiber for Mass Transit Transportation., Collaboration with Materials Innovation Technologies (MIT)
- Laurel Biocomposites– Research in bioresin and biocomposites for use in automotive and mass transit

Technical Accomplishments



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

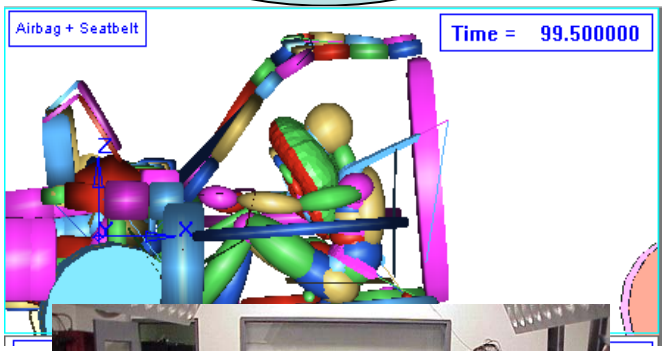
Advanced Composites Technologies

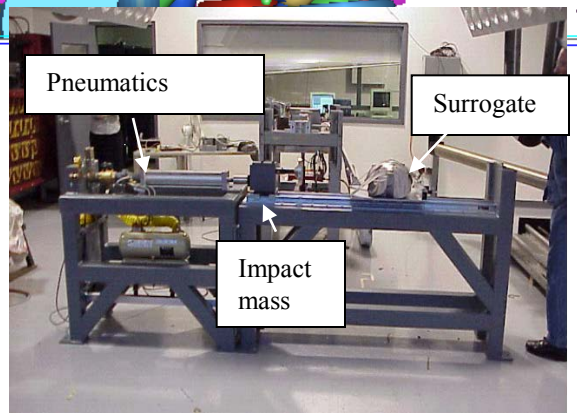
Advanced Metal Casting Technologies

Automotive castings

Advanced materials for automotive safety

High fidelity computations for crashworthiness studies



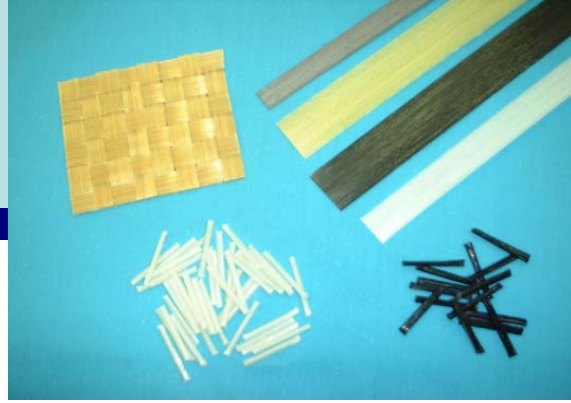


Lightweight materials for highway safety

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 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

Materials Forms for Thermoplastic 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

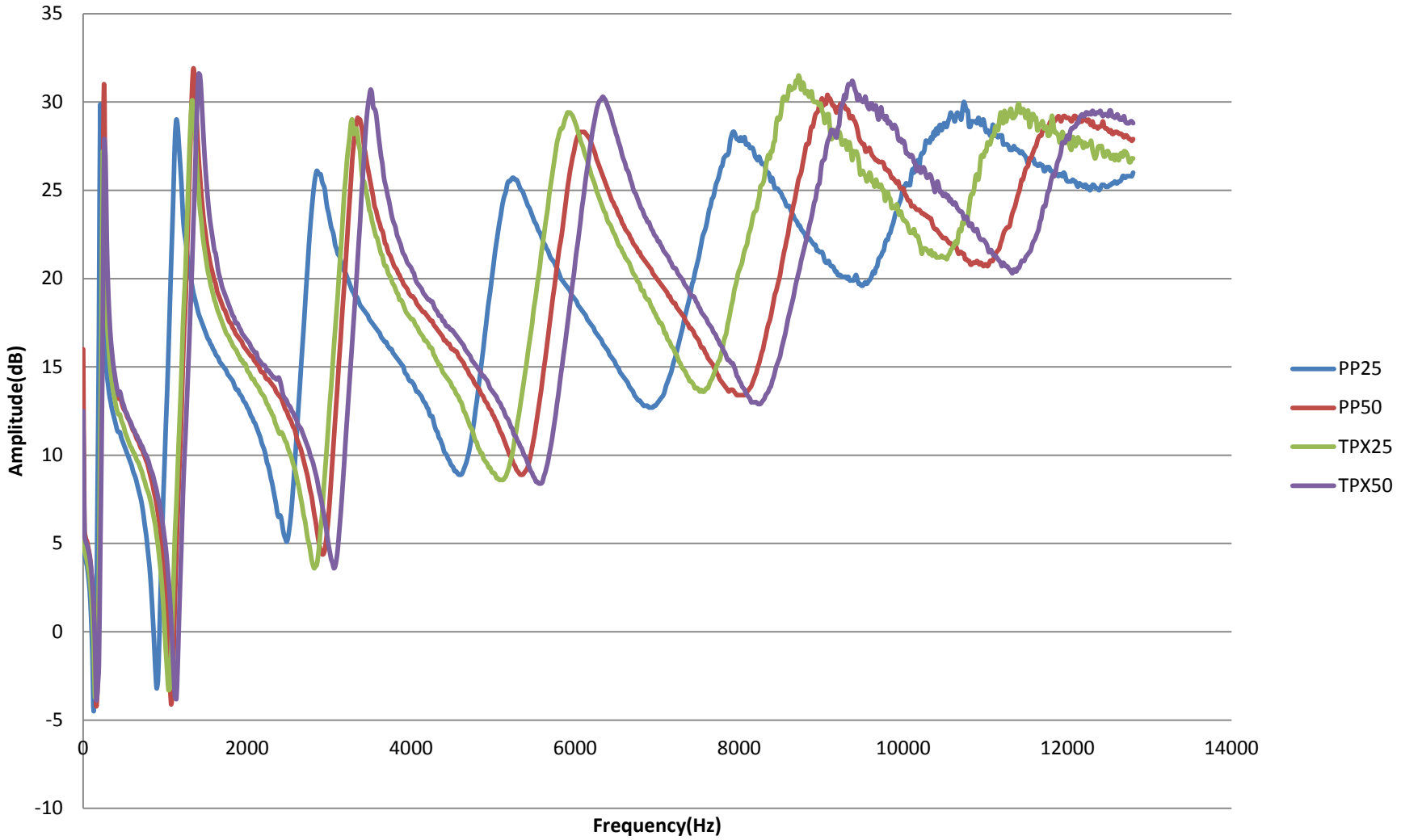
(INJECTION MOLDING, EXTRUSION, COMPRESSION MOLDING, DIAPHRAGM FORMING, THERMOFORMING, PAINTING, JOINING, ETC…)

END PRODUCT

GATE scholars are being trained in materials compounding and lightweighting

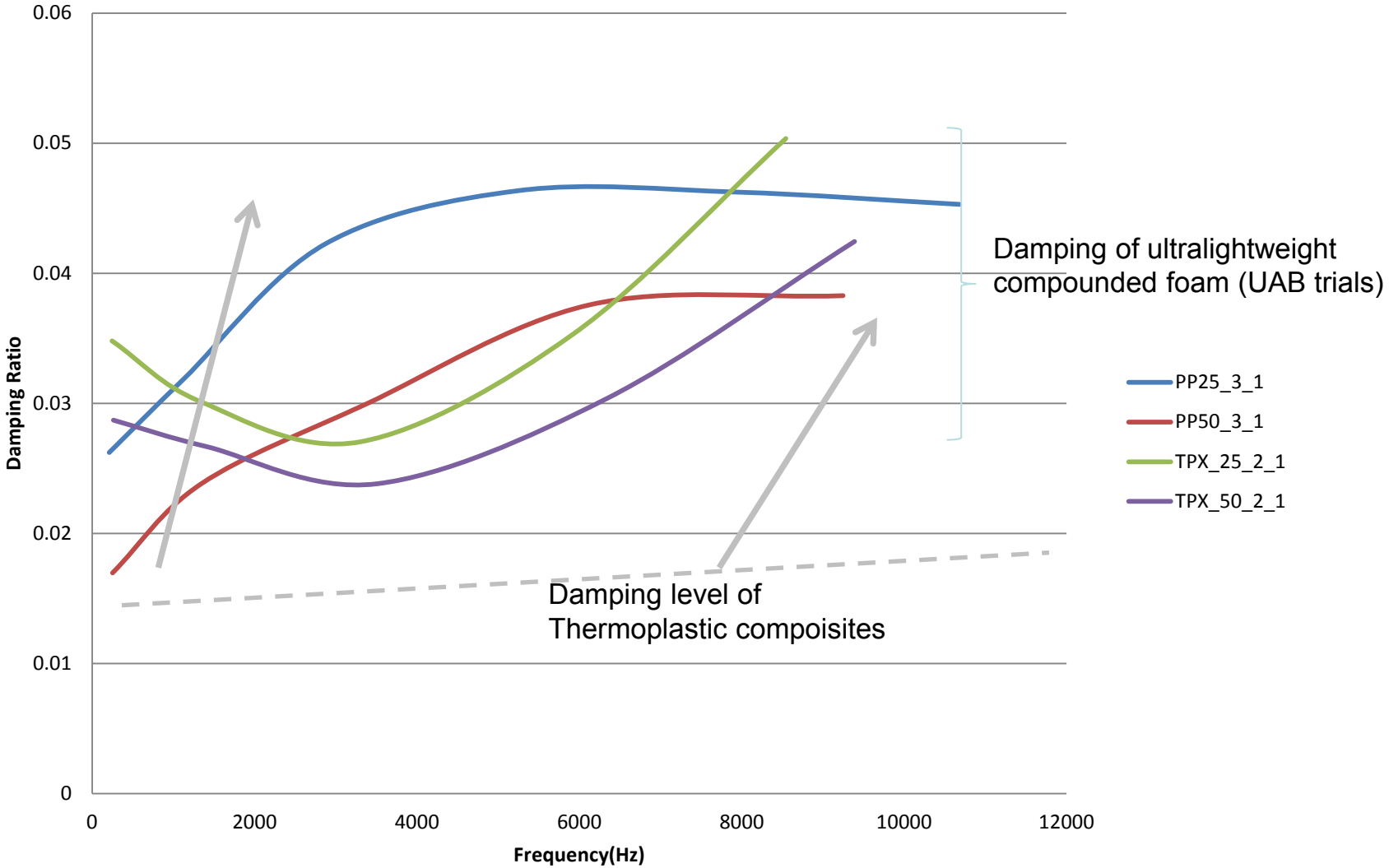
- Leistritz Micro 18 Twin Screw Extruder
- Co-rotating screws
- Screw Diameter (D): 17.8 mm
- Screw Functionary Length: 40D
- No. of Heating Zones: 7
- No. of Cooling Zones: 6

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

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)
- Successfully impregnated Polypropylene and Polyamide thermoplastics on carbon fibers sized for epoxy, vinyl ester and unsized PAN fibers. Impregnation quality is excellent; physical, static & dynamic mechanical property evaluations are underway.
- Successfully impregnated carbon fiber with poly ether imide resin
- These material options can be used by the automotive and transportation industry in number of broad good applications for exterior and interior structural panels.

Flax and Kenaf Fiber Composites Development
Student - Theresa Bayush (GATE Scholar)

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.

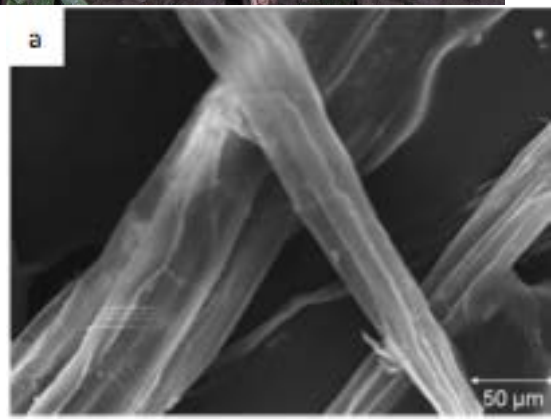
- Natural fibers present some challenges:
  - High Moisture uptake
  - Low thermal stability
  - Low bonding with polymers
- Chemical treatments can improve the fiber performance.
- The effect of a chemical treatment with NaOH solutions on the properties of natural fibers and the resultant composites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

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



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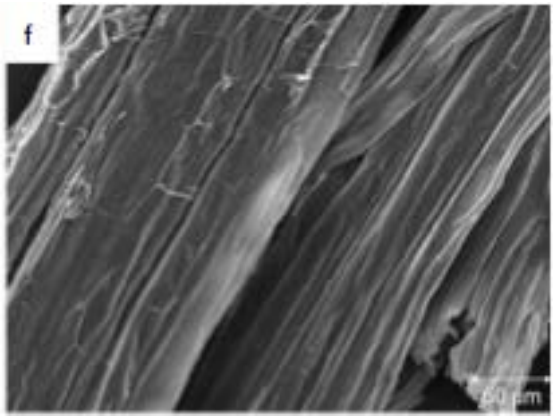
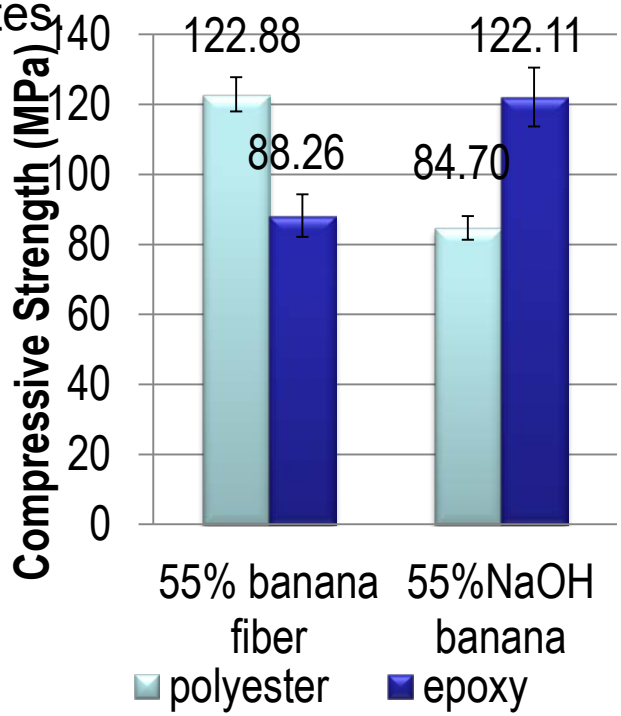


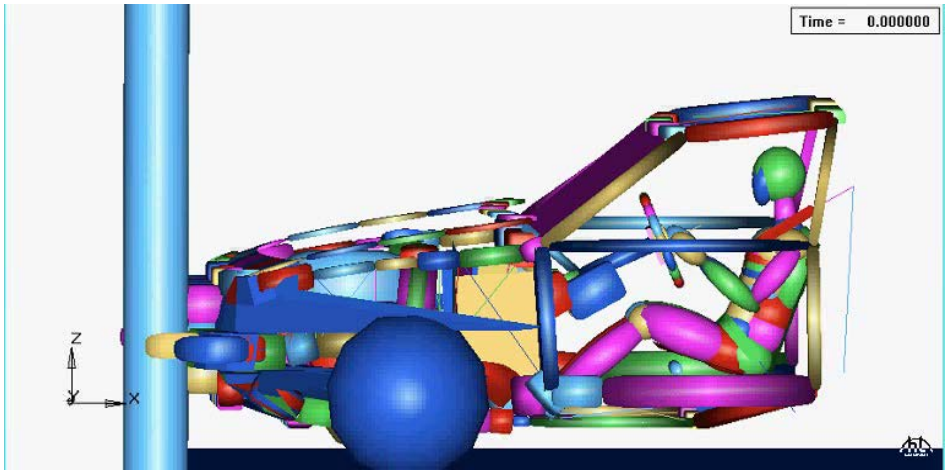
NaOH treated



Crash modeling and Injury Biomechanics

Multi-Body Dynamics

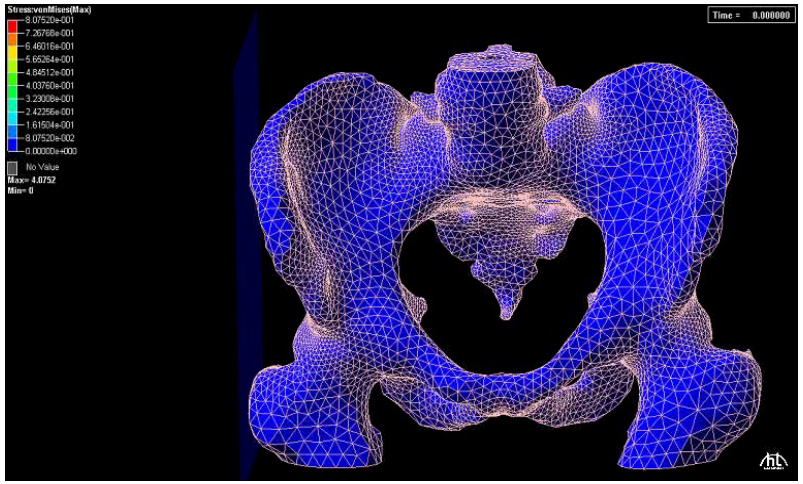
- Multi-body system comprised of rigid and/or flexible bodies
  - Joined together by kinematic joints
  - Acted on by forces
  - Systematic and efficient algorithms for governing equations of motion
- Commercial codes : MADYMO, ADAMS, DADS, etc.



MADYMO simulation :
A vehicle with dummy impact to a pole

Finite Element Methods

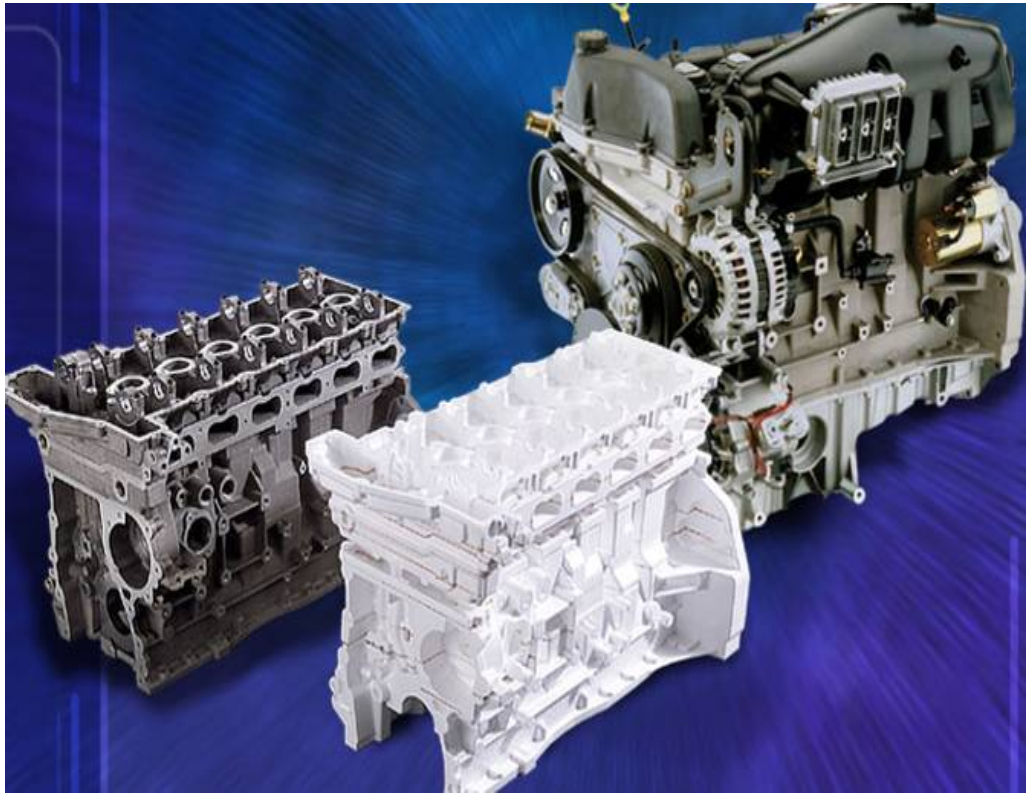
- Can be applied to all of engineering fields
  - Dynamic solution of structural system
  - Solve governing equilibrium equation for finite element discretized in space
  - A variety of material constitutive models
- Commercial codes : LS-DYNA, PAM-CRASH , RADIOSS, etc.

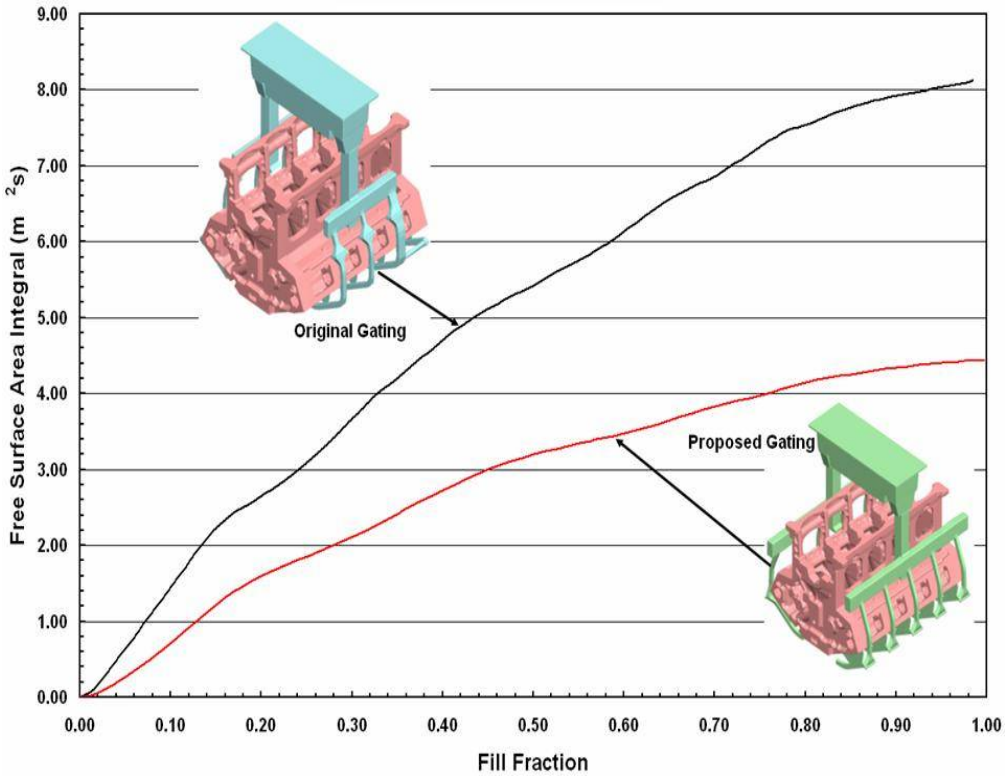


LS-DYNA simulation :
Side impact of a human pelvis

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.

GATE Work with Daimler Truck North America (DTNA) – GATE Scholar Khongor Jaamiyana

- The UAB GATE team has initiated a lightweighting effort with DTNA, Portland, Oregon for a heavy truck door application. DTNA is looking at reducing weight from their cabin access door which is about 0.8 m x 0.4 m in exterior dimensions. Presently, this door is made with thin gauge aluminum sheet metals with small steel plates at critical mounting points.
- The UAB GATE mission of working with industry in offering lightweight composite solutions is directly relevant to this effort. Engineering drawings have been received from DTNA. The team has worked on the integrated design, process and product development (IPPD) approach. The basic CAD and finite element analysis of a composite door has been completed.
- The composite door will provide 25-40% weight savings at comparable cost to the metal door.
- The work is now transitioning to prototype tooling and parts development in the Spring 2012 period.

Significant progress has been made with the collaboration with MITRCF, South Carolina. MITRCF is the world leader in recycling carbon fibers from a vast range of resources – including decommissioned aircraft, sports gear such as hockey sticks and carbon fiber reject bicycles, out of life pre-preg and others. MITRCF has technology to recycle the carbon fiber and produce intermediate forms such as roll good stock and a slurry process where the fiber are deposited on a tool for three-dimensional deposition.

Several transportation applications using recycled carbon fibers were featured. Seven UAB GATE scholars visited MITRCF on January 6th, 2012 to tour the MITRCF plant and have technical discussions on recycled carbon fiber technology.

Dr. Mark Janney and Mark Mauhar of MIT discussed the technology details with the GATE scholars and this was an excellent opportunity for the students and staff to get first hand information on emerging carbon fiber technology for automotive use.

GATE work with Composites Innovation Center (CIC), Manitoba, Canada; GATE Scholar – Theresa Bayush

In this GATE collaboration effort, GATE scholars are working with Composite Innovation Centre (CIC) and its industrial partner on designing and prototyping a bio-composite component. This component is a dashboard that consists of multiple parts for a car. CIC is working with UAB GATE on the design and processing of dashboard parts.

The work is investigating light weighting of the component in conjunction with requirements of bio-content. The component is to be resistant to ultraviolent rays and 'scratch' resistant.

The work is divided into the following steps; (a) Resin type - thermoplastic/ thermoset; biodegradability and transition temperature; (b) Fiber type(s) - hemp, flax, jute, and/or kenaf, chemical treatment and additives and recycled carbon fiber; (c) Processing techniques and (d) Material testing.

GATE Workshops and Outreach

- March 29-30, 2012: Thermal Analysis Workshop offered in collaboration with TA Instruments. 40 participants from UAB, Tuskegee, UA, Miles College and Industry attended the GATE workshop to learn about DSC, TGA, DMA, TMA and related thermal analysis techniques
- GATE workshop for high school students being offered – April 16-17, 2012 – 30 participants
- GATE activities were featured at the American Composites Manufacturing Association (ACMA), Las Vegas Exhibition Booth, February 22-24, 2012
- GATE activities are being featured at the Techtextil Conference, Exhibit Booth, Atlanta, GA, April 24-26, 2012
- Website reporting GATE activities is updated – www.uab.edu/composites

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

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	Polystrand	Glass/PP recycled and Body Panels
7	Trelleborg of Boston (TOB)	Syntactic foam microballoons
8	Materials Innovation Technologies (MIT)	Recycled carbon fiber for transportation
9	Jordan Reduction Solutions (JRS)	Shredding of scrap for recycled composites
10	Neenah Paper	Carbon fiber thermoplastic mats for transportation
11	Daimler Trucks North America	Lightweight composite cargo doors
12	Composites Innovation Center (CIC), Canada	Natural fiber composite parts for automotive

Educational Partners

#	Collaboration	Interaction
1	Lawson State Community College, AL	2-year college/Student Pipeline / Workshops
2	Tuskegee University, 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	Bevill State Community College, Decatur, AL	Student Pipeline/ Workshops
6	Oak Ridge National Laboratory, TN	Guidance & Program Relevance

New Book – Educational Resource for practicing composite engineers, end-users, R&D teams and academia

DOE Merit Review
May 2012

SPECIAL OFFER to attendees of the SPE Automotive Composites Conference & Exhibition (ACCE)

NEW BOOK
Order Today!
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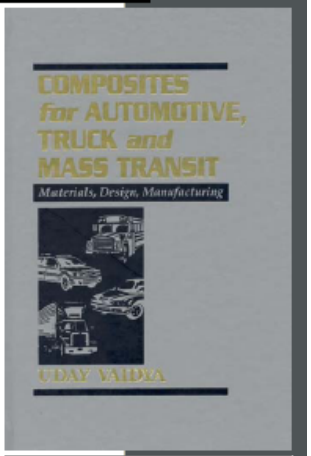

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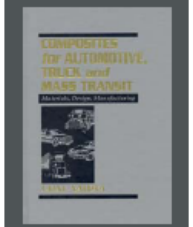

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Summary of Progress towards GATE Goals and Objectives

- ✓ Support 3 graduate students/year - 4 *graduate students have been supported to date by GATE funds*
- ✓ Support 4 undergraduates each year –*undergraduates have been supported to date*
- ✓ Develop and offer two new automotive related courses per year to impact 20 to 30 students per year –*GATE courses are offered as planned and on track*
- ✓ Influence at least 30 students per year through hands-on workshops – *GATE workshops have been offered as planned*
- ✓ 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*

Acknowledgements

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- Collaborators – Tuskegee University, Lawson State and Bevill State Community College