Advanced Materials and Processing of Composites for High Volume Applications (ACC932)

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June 9, 2010

Project ID #LM021

Overview – CF SMC

Timeline

- Start – May 2007
- End – December 2012
- 40% Complete

Budget

- Total ACC932 project funding
  - DOE share: $2,871K
  - Contractor share: $2,880K
- Funding received in FY09
  - $40K
- Funding for FY10
  - $75K

Barriers

- Barriers addressed
  - Technical; Performance and Manufacturability
  - Market: Cost and Inadequate Supply Base

Partners

- Continental Structural Plastics, a Tier One supplier
- Zoltek, carbon fiber manufacturer
- Huntsman, epoxy resin system

Objectives

Advanced Materials and Processing of Composites for High Volume Applications (ACC932)

Carbon Fiber SMC – Develop high-performance, cost-effective, carbon fiber SMC materials and associated processing techniques for high-volume automotive components. This will allow OEM's a chance to implement both Class-A and structural applications that allow significant weight savings coupled with superior mechanical performance.

Carbon Fiber SMC

Milestones

Month/ Year	
May/2008	Install carbon fiber SMC compounding equipment modification.
Dec/2010	Develop a resin system compatible with carbon fiber reinforcement. Fiber bundle spreading is a critical component for proper wet-out of the carbon fibers.
Jun/2011	A low cost structural carbon fiber will be incorporated with an optimized resin system and compounding process to produce a cost effective carbon fiber SMC package.
Jun/2012	Structural carbon fiber SMC will be refined to provide a class "A" surface appearance material system for automotive applications
Dec/2012	Documentation to allow Tier-1 suppliers to use carbon fiber SMC for OEM usage.

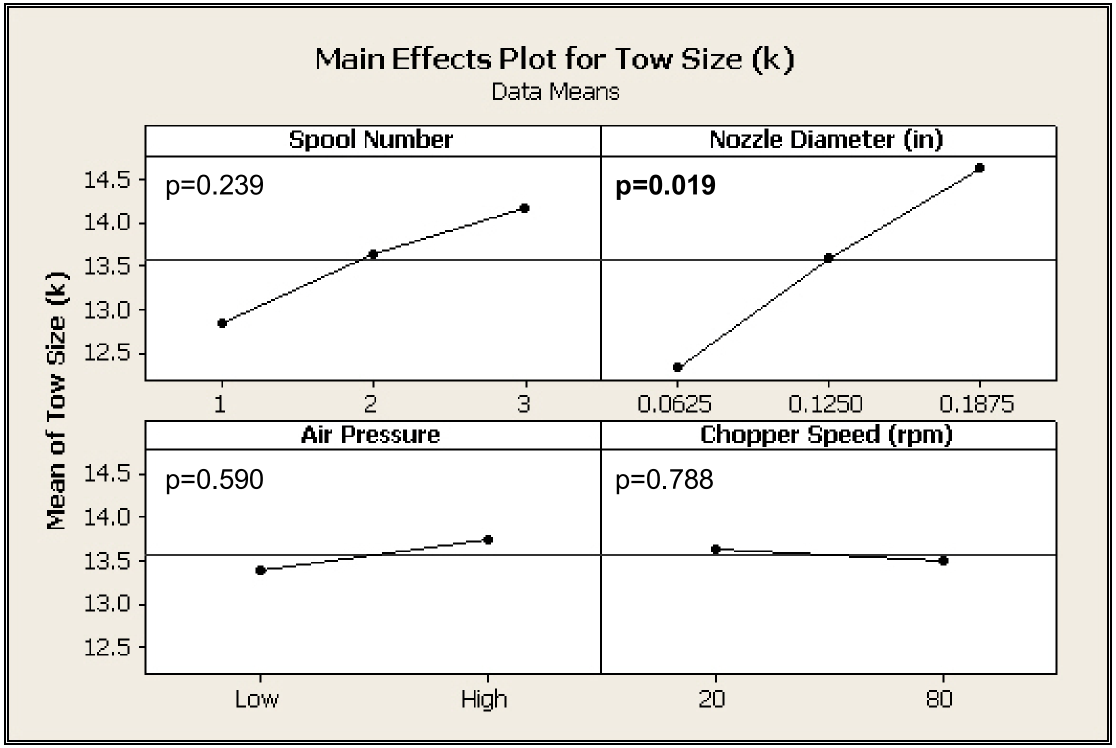
Carbon Fiber SMC

Approach

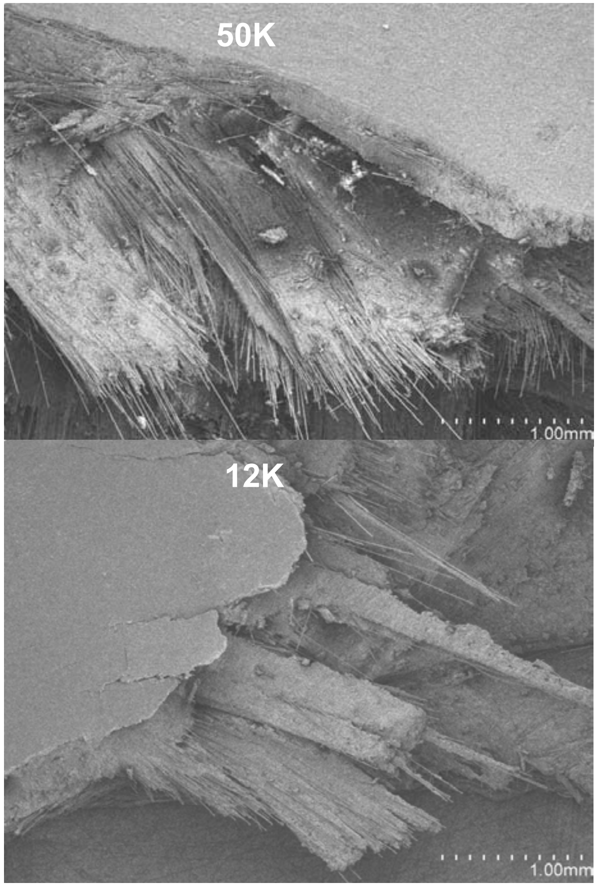
- Initiate studies with Tier-1 and 2 resin and fiber supply base to understand their capabilities and what they are able to add to the project objectivities.
- Compound carbon fiber SMC and characterize mechanical properties to compare against current state-of-art systems.
- Modify SMC compounding machine/process to allow for improved wet-out of SMC composite.
- Develop and start carbon fiber bundle spreading experiments to maximize mechanical properties.
- Investigate optimizing the compounding process for enhanced consistency and cost effectiveness.
- Focus on optimizing the structural compound to enhance its appearance for visible automotive applications.

Carbon Fiber SMC

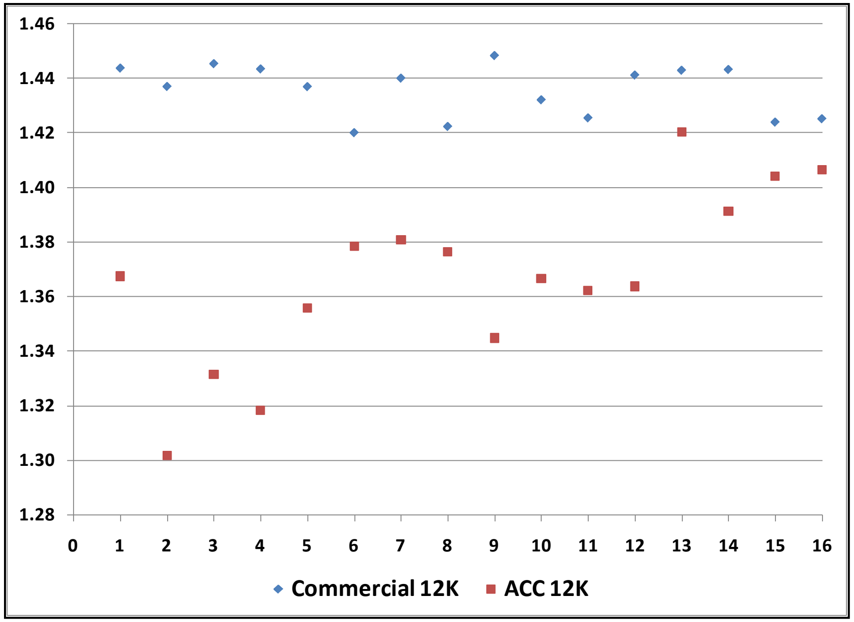
- In 2008 equipment was modified, materials were evaluated, and fiber "sizing" studies were made.
- In 2009 the "air knife" concept was explored in a designed experiment to enhance de-bundling of the carbon fibers. De-tensioning the bundle will be added.
- In 2009 multiple trials indicate very fine lines between having dry fiber bundles, wetting out the carbon fiber bundles, and losing bundle integrity during compounding.



Carbon Fiber SMC



- Commercially available carbon fiber SMC had smaller density variations



- Fracture surfaces suggest failures seem to be occurring between bundles

Carbon Fiber SMC

Collaborations

- **Partners**
  - Continental Structural Plastics (CSP); resins and compounding
  - Zoltek; carbon fibers and sizing
  - Huntsman; alternative resins
  - National Composite Center; compounding

- **Technical Transfer**
  - Collaborate with CSP, Huntsman, and Zoltek to implement into high volume applications
  - OEM’s to define prototype component for full prove out
  - OEM’s to determine opportunities for future implementation

Carbon Fiber SMC

Future Efforts

1. Refine understanding of critical compounding variables; such as compaction pressure, compounding temperature, resin viscosity, and resin/fiber ratios. This supports the milestone for proper wet-out of the carbon fiber bundle.
2. Using lower cost carbon fibers, evaluate low cost methods to "debundle" the carbon fibers; such as bundle spreading, air blasts, de-tensioning, and an alternative chopper system. This supports the low cost milestone.
3. Study additives and resin modifications to enhance the surface appearance of the molded material.
4. Mold developmental parts for potential OEM applications.

Overview BLRT

Timeline

- Start - May 2005
- Finish – October 2010
- 85% Complete - 85

Budget

- Total ACC932 project funding
  - DOE share: $2,871K
  - Contractor share: $2,288K
- Funding received in FY09
  - $260K
- Funding for FY10
  - $380K

Barriers

- Robust Joining Technologies for Polymer Composites
- Barriers to Implementation of Thinner Class-A Composites Body Panels including Carbon Composites
- Affordable Carbon Composites

Partners

- Interactions/ collaborations
  - Multimatic Engineering Services Group
  - Continental Structural Plastics (CSP)

Objectives

Advanced Materials and Processing of Composites for High Volume Applications (ACC932)

BLRT – Enable implementation of minimum thickness composite closure panels to eliminate weight added for appearance by developing a validated finite element (FE) model that can predict, and therefore allow design optimization of, the severity of BLRT distortions based on part design. This will allow OEMs to implement minimum thickness
composite closure panels while still meeting customer expectations for surface quality.

Bond-Line Read-Through

Milestones

Month/ Year	
5/2008 **Complete**	Phase 1: Develop a measurement system capable of quantifying the visual severity of BLRT-induced distortions
8/2010 Planned	Phase 2: Experimentally determine the material and process factors that are the root cause of BLRT. Completion of all experiments, including part validation experiment.
1/2010 **Complete**	Phase 3: Determine material models required to correctly predict BLRT-induced distortions using finite element modeling.
9/2010 Planned	Phase 3: Establish design and manufacturing guidelines for eliminating visible distortions in production parts and methodologies for updating those guidelines upon adoption of new materials (i.e. Class "A" carbon fiber SMC).
10/2010 Planned	Project Documentation: Peer reviewed journal papers summarizing the material and process factors that contribute to BLRT and the design and manufacturing guidelines for eliminating visible distortions.

Bond-Line Read-Through

Approach

- ***Phase 1 – Measurement Development*** ✓ Complete
  - Develop a measurement for quantifying the visual severity of bond-line read-through induced surface distortions that correlates with visual assessments
- ***Phase 2 – Experimentally Determine BLRT Root Cause***
  - Experimentally determine which material and process factors are the primary contributors to BLRT
  - Create experimental data to validate analytical models

  90% Complete
- ***Phase 3 – Develop an Analytical Model for Predicting BLRT***
  - Determine the material properties and analytical modeling techniques necessary to predict BLRT-induced distortions
  - Identify design principles to minimize the occurrence of BLRT and allow OEMs to use minimum thickness outer panels in closures

  80% Complete

Bond-Line Read-Through

FY09 Technical Accomplishments

- ***Phase 2 – Determine BLRT Root Cause***
  - SMC Formulation Experiment
    - Established that the bending stiffness of the panels is more important than the material stiffness
    - Established that the coefficient of thermal expansion (CTE) is an important factor
    - Established that inner panel thickness does not effect BLRT severity
  - Bond Stand-Off Experiment
    - Demonstrated that changes in the bead shape drive BLRT severity
    - Demonstrated that differences between the CTE of the adhesive and the SMC are a primary factor in BLRT
  - Finite Element Validation Experiment
    - Created data specifically for comparison to finite element models
    - Validation of previous experimental results
  - BLRT Fading Experiment
    - First data to demonstrate the extent to which BLRT fades over time
    - First data on the effect of subsequent processing on BLRT severity

Have now Experimentally Established Primary Causes of BLRT

Bond-Line Read-Through

FY09 Technical Accomplishments

- ***Phase 3 – Analytical Model for Predicting BLRT***
  - Determined the finite element model configurations and post-processing methodologies needed to predict BLRT
  - Predicted stresses based on linear-elastic material models exceeded adhesive yield stresses, indicating more realistic material models were necessary
  - Comparison of predicted curvature profiles to experimental data demonstrated that FE models using linear-elastic material models over-predict the curvature in the surface
  - Analysis of the bond stand-off configuration, even using linear elastic material models, was used to clarify the physics responsible for the experimental results

Have Determined what is Required to Predict BLRT Severity

Bond-Line Read-Through

Collaborations

- **Partners**
  - Multimatic Engineering Services Group
  - Continental Structural Plastics (CSP)

- **Technical Transfer**
  - Working directly with the Tier I supplier who will implement reduced thickness panels
  - Will publish “Bond-Line Read-Through Explained”
    - Part 1 – Root Causes of BLRT
    - Part 2 – Design and Manufacturing Guidelines for Eliminating Visible BLRT-Induced Distortions

Bond-Line Read-Through

Future Efforts

- ***Phase 2 – Experimentally Determine BLRT Root Cause***
  - Bond Stand-off Design & Hard Hit Experiment
  - Effect of Time Between Process Steps on BLRT Severity
  - Hot Air vs. Electric Fixture Experiment
  - Bead Shape Validation Experiment
  - Final Component Validation Experiment
- ***Phase 3 – Develop an Analytical Model for Predicting BLRT***
  - Develop viscoelastic material models for three adhesives
  - Validate model predictions for those three adhesives
  - Complete an analytical DOE to determine manufacturing tolerance guidelines for adhesive bead geometry
  - Complete and analytical study to determine impact of global component shape on BLRT distortion severity

All project tasks, other than final documentation, will be complete by the end of FY10

Objectives

Advanced Materials and Processing of Composites for High Volume Applications (ACC932)

Direct Compounding of Thermoplastic Composites (D-LFT)
- Establish a low cost processing method for manufacture of high performance lightweight thermoplastics composites. Determine processing parameters, customize master batch formulations for Nylon material, establish composite material properties, investigate processing equipment and tooling design and develop Tier-1 supplier interface.

Overview – D-LFT Composites

Timeline

- Start – March 2009
- End – December 2011
- 10% Complete

Barriers

- Barriers addressed
  - Technical; Performance and Manufacturability
  - Market: Cost

Budget

- Total ACC932 project funding
  - DOE share: $2,871K
  - Contractor share: $2,880K
- Funding received in FY09
  - $10K
- Funding for FY10
  - $131K

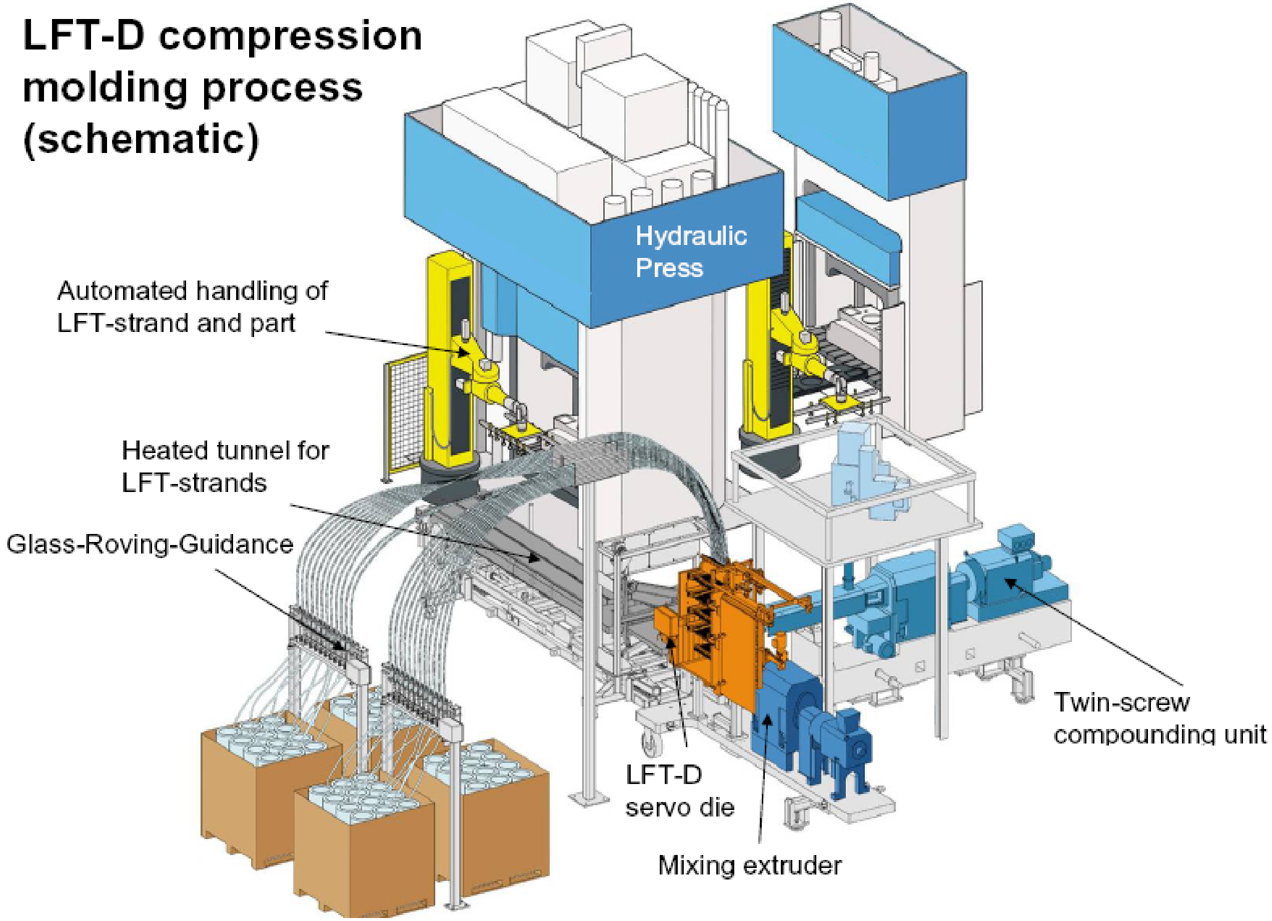
Partners

- Continental Structural Plastics, a Tier One supplier
- National Composite Center
- Dupont, Nylon resin supplier

Affordable Vehicle Weight Reduction through Direct Compounding

Month/ Year	**Milestones**
3/2009	Project proposal raised for review by ACC932 working group. Fraunhofer ICT was approached as a potential project partner. However, Fraunhofer ICT would not entertain USAMP terms and conditions. Instead, Meridian Automotive secured as Tier 1 partner for cost share and co-development of D-LFT composites.
7/2009	Meridian Automotive file for bankruptcy. Magna purchased Meridian assets and severed working relationships with ACC. To prevent further delays a new D-LFT project plan was kicked off in the absence of a Tier 1 partner. DuPont agreed to collaborate, supplying materials for formulation development and benchmarking.
7/2009	First set of processing trials completed at the National Composites Center to determine feasibility of using the extrusion compression process for PA composites.
10/2009	Completed mechanical property testing of pre-compounded samples to establish benchmark properties for D-LFT formulations under development by the ACC932 team.
1/2010	Generated initial, heat stabilized, D-LFT formulation proposals based upon polyamide 66 composites. Potential application to underhood and other high temperature components.
4/2010	First batch of PA66 based D-LFT materials produced at a toll compounder (using Coperion compounding equipment in Newark, NJ)

Schematic of Direct Compounding Process



Slide courtesy of Dieffenbacher

D-LFT Composites

Approach

- **Phase 1 – Establish Technical Feasibility of Processing Engineering Thermoplastics by Extrusion Compression Molding.**
  - Using compounding facilities at NCC, processed DuPont PA66 materials on a single screw extruder to determine effect of atmospheric exposure (oxidation) on mechanical properties of PA based composites.
- **Phase 2 – Generate Test Samples of Pre-Compounded Materials to Establish Target Properties for Subsequent D-LFT Formulations**
  - Completed impact and tensile testing of PA66 samples. Properties were in line with expectations, suggesting that short term atmospheric exposure of the polymer melt was not detrimental to part properties.
- **Phase 3 – Establish Low Cost Polyamide Based Formulations**
  - Complete formulation development based upon polyamide 66 systems.
  - Complete D-LFT molding studies and testing programs to establish performance against objectives.
  - Determine feasibility of processing different reinforcement options - glass fiber / carbon fiber (both virgin & recycled)
  - Complete cost comparison of D-LFT formulations against pre-compounded materials.

D-LFT Composites

Technical Accomplishments

- Proven feasibility of polyamide D-LFT Process
- Established property data for polyamide composites with 30wt% and 50wt% fiber loading.
- Established first generation formulation for testing.
- Completed first series D-LFT compounding trials

D-LFT Composites

Future Efforts

- Complete D-LFT compression molding trials and testing of first generation material formulation.
- Perform injection molding studies to determine molding characteristics of new formulation and performance against conventional (pre-compounded) injection molded pellets.
- Complete cost analysis of D-LFT process to verify business case.
- Direct future material formulation development on a component for technology demonstration.

ACC 100
Predictive Technology Development and Crash Energy Management

Khaled W. Shahwan, PhD – Project Leader
Chair – ACC100

2010

This presentation does not contain any proprietary, confidential, or otherwise restricted information

ACC100 Overview

Timeline

- Project start: 2007
- Project end: 2012
- Percent complete: 65% (approx.)

Barriers

- Materials' cost & availability
- Materials' characterization & testing standards
- Universally robust and truly predictive modeling tools
- Complex physics of crush

Budget

- Total project funding:
  - $1,540K (2007-2012) (approx.)
  - Cooperative Agreement
- FY08 funding: $400K (approx.)
- FY09 funding: $425K (approx.)
- FY10 funding: $190K (approx.)

Collaborators

- Chrysler
- Ford
- GM
- University of Michigan
- Northwestern University
- Rensselaer Polytechnic Institute
- Nottingham University (UK)

ACC100 Objectives

- Investigate which major structural members can be re-designed using lightweight fiber-reinforced automotive composites without degrading crashworthiness and structural safety.
- Investigate which leading materials’ candidates (fibers, matrix/resin, architecture) can be the most viable for crashworthiness that lead to increased strength, stiffness, energy absorption while reducing component structural mass by at least 50%.
- Characterize such materials by measuring their mechanical properties.
- Design and build structural tubes of various configurations using the above materials and perform quasi-static and dynamic crush tests to assess their energy absorption.
- Develop computer models to analyze vehicle structures using such advanced materials. The mostly phenomenological models proved to be a useful simulation tool albeit not “truly” predictive on a robust basis—***truly predictive tools are needed.***
- Employ all of the above information and know-how to demonstrate such technologies.

% Achieved = 100%

ACC100 Objectives … *Cont’d*

- Characterize nonlinear composites’ properties and their constituents within a hierarchical framework (manufacturing, life cycle) for automotive applications.
- Characterize the dominant micro-, meso-, and macro-mechanical mechanisms responsible for damage initiation, progression, and energy absorption.
- Characterize the coupled material-structural (local-global) behavior of composites in order to direct the development of new and improved material systems and models.
- Develop, verify and validate efficient and robust modeling and analysis tools for the prediction of damage initiation, progression, energy absorption, and overall crush behavior of composite components in lightweight vehicle structures using state-of-the-art micromechanical, phenomenological and hybrid approaches.

% Achieved (as of Q4 2009) **≈ 65%**

ACC100 Major Achievements

- Identified carbon braided textiles as a material candidate with significant weight savings (e.g., ~1400 kg/m^3—80% lighter than common steels) for strength and crashworthiness of primary structural applications.
- Identified and characterized the dominant micro-, meso- and macro-mechanical and material damage initiation, progression and crush energy absorption mechanisms, and the nonlinear composites' properties within a hierarchical framework for automotive applications.
- Characterized the coupled material-structural (local-global) behavior of composites for the direct development of new and improved material systems and state-of-the-art computational models aimed at crashworthiness applications within the automotive industry.
- Developed and verified efficient and robust modeling and analysis tools for the prediction of damage initiation, progression, energy absorption, and overall crush behavior of small-scale specimens made of advanced lightweight composites using state-of-the-art micromechanical, phenomenological and hybrid approaches. *This is on-going and is being expanded for further validation on larger structural components.*

ACC100 Projects

To understand, model and predict the crush process of advanced lightweight composite structures for automotive applications, the ACC100 has initiated, supported and led numerous projects—many have been completed, few are on-going.

The following slides highlight some of ACC100's recent projects:

- Multiscale Modeling for Crash Prediction of Composite Structures
- Static and Dynamic Crush of Random Carbon Fiber Structural Tubes
- Size Effects in Textile Carbon Composites
- Modeling of The Manufacturing Process Induced Effects on Matrix Properties of Textile Composites

Multiscale Modeling for Crash Prediction of Composite Structures

Overview:

Research Contractor: Rensselaer Polytechnic Institute

Duration: 1 year (Phase I); and 1 year (Phase II)

Budget: $102K (Phase I) (total)
$110K (Phase II) (total)

% Completion: Phase I – 100% complete
Phase II – 95% complete

Objectives:

1. To develop a multiscale modeling tool to simulate the static and dynamic crush of large automotive structural components (e.g., axial crush of tubes) made of fiber-reinforced textile composites
2. The tool must be capable of efficiently simulating the overall structural response while significantly reducing full model order/size
3. The tool need to be deployable within a commercial FEA solver and must be able to robustly simulate static and dynamic crush-loading conditions

Approach:

1. Collect mechanical properties from tube crush, coupon, and interface/interphase test data
2. Develop a mathematical up-scaling (from fine to coarse levels) using homogenization
3. Develop a computational up-scaling (to reduce the complexity of full micromechanical model)
4. Identify dominant parameters from representative sub-sets based of experimental data optimization
5. Develop a GUI to interface and channel the above into a commercial nonlinear FEA solver

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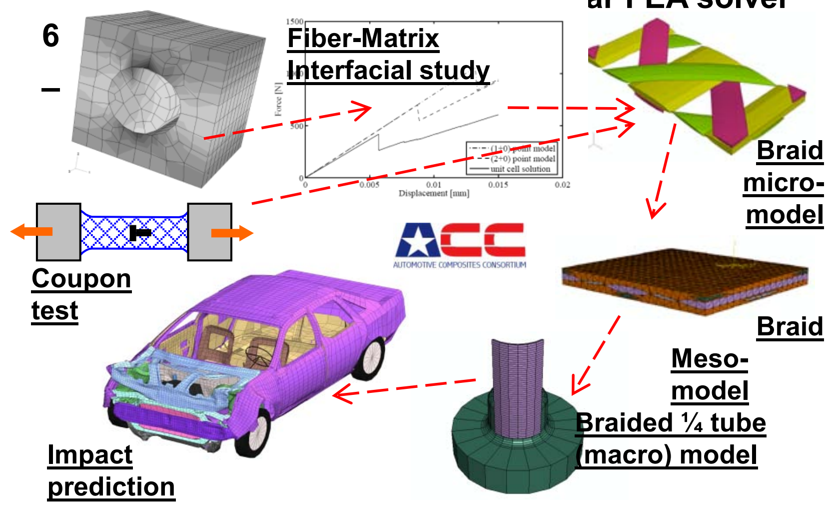
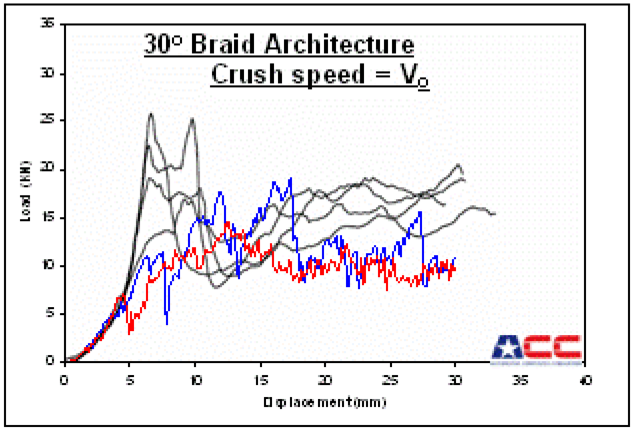
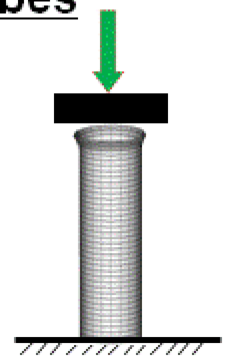


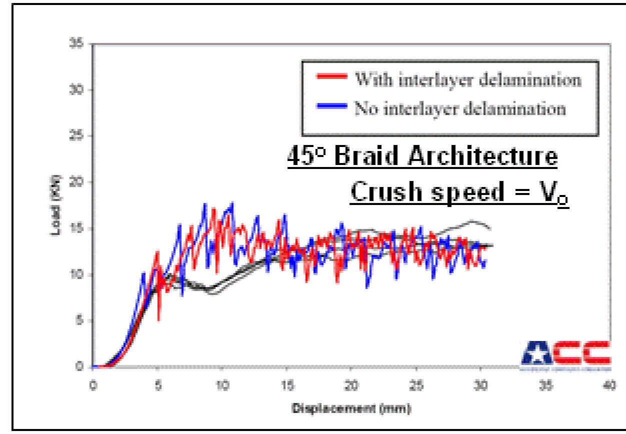
Multiscale Modeling for Crash Prediction of Composite Structures

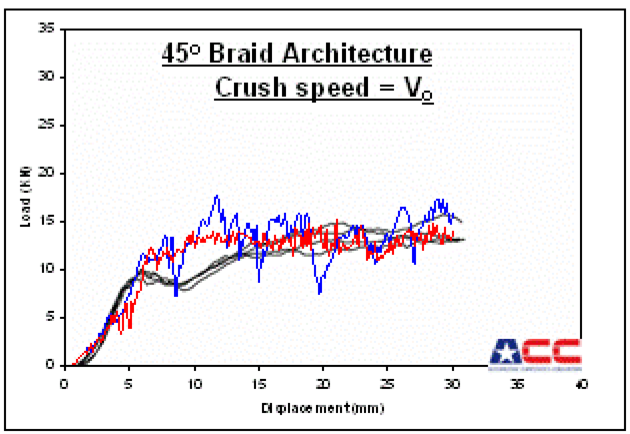
Highlights of Sample Results (Modeling & Testing):



Braided Carbon Tubes





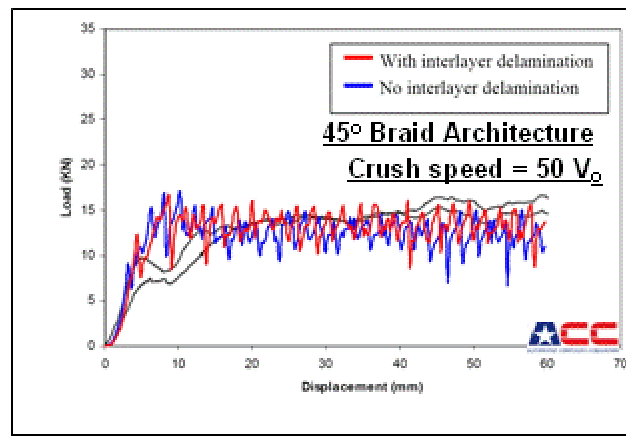


Tests

Model A

Model B

All result are preliminary



Static and Dynamic Crush of Random Carbon Fiber Structural Tubes

Overview:

Research Contractor: University of Nottingham

Duration: 1 year

Budget: $76K (total)

% Completion: 75% complete

Approach:

1. Select materials and geometries according to prior knowledge and other testing/manufacturing constraints
2. Manufacture flat plaques (for material characterization and testing coupons)
3. Manufacture tubes according to the testing matrix
4. Perform static-test permutations.
5. F

Tubes’ cross-sectional geometries

Objectives:

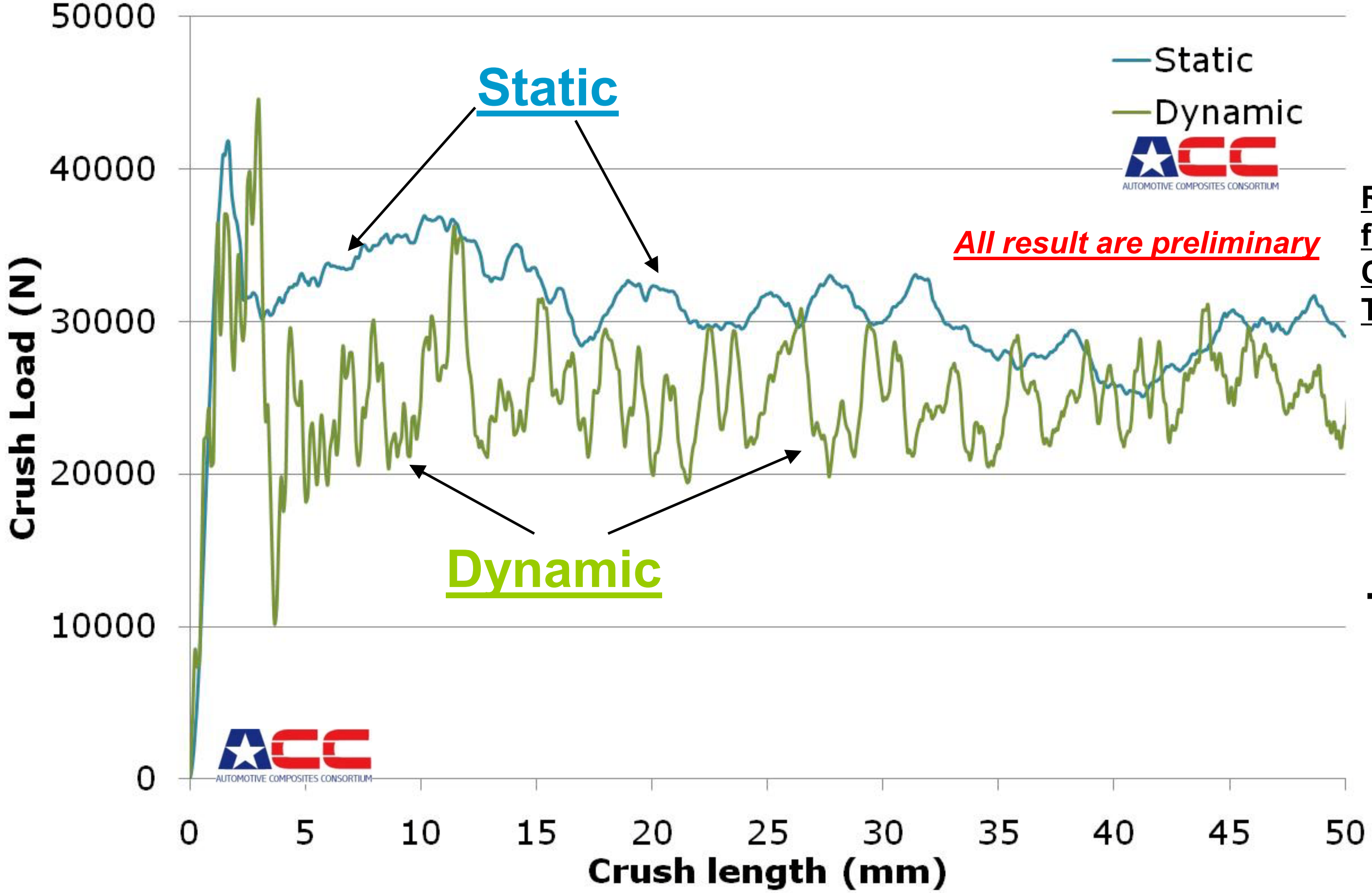
1. To identify trends in energy absorption of discontinuous carbon fiber composite tubes while varying common architectural parameters: e.g., fiber length, tow size, tube geometry (cross-sectional shape, wall thickness).
2. To investigate the effect of loading rates (static vs. dynamic) on the specific energy absorption (SEA) characteristics.

Tube manufacturing

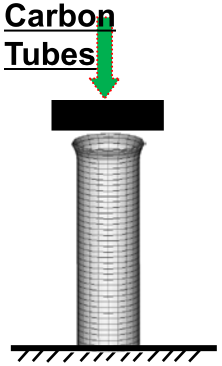
Crushed circular and square tubes

Static and Dynamic Crush of Random Carbon Fiber Structural Tubes

Highlights of Sample Results (Testing):



Random fiber Carbon Tubes



Size Effects in Textile Carbon Composites

Overview:

Research Contractors: University of Michigan
Northwestern University

Duration: 2 years

Budget: $467K (total)

% Completion: 90% complete (on-going)

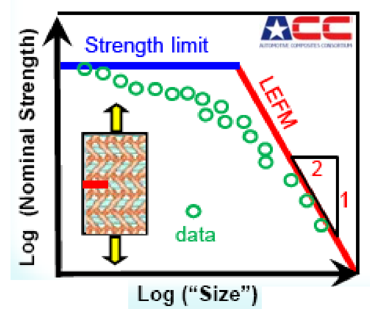
Approach:

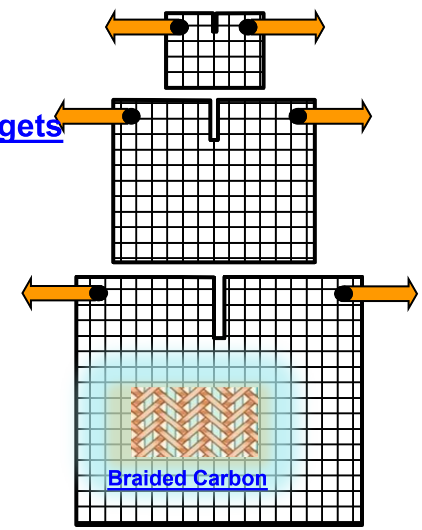
1. Carry out an extensive testing program on different carbon braid architectures and different coupon/plaque sizes with different damage sizes
2. Develop novel methods to efficiently model large specimens using micro-mechanics coupled with damage evolution/progression mechanisms
3. Carry out characterizations under quasi-static and dynamic loading conditions
4. Implement into FEA of carbon braids, & recommend ways to incorporate size effects in modeling practices & testing standards

Objectives:

1. To extensively investigate via experiments Size (Scale) Effects' presence in braided carbon textile composites. *["Size" here refer to damage (crack) size w.r.t. structural size, not finite element mesh size w.r.t. structural size (not mesh sensitivity)]*
2. To develop novel validated approaches to model, predict and incorporate size effects efficiently in material models of large carbon-braided textile composites using commercial FEA solvers
3. To develop and recommend modeling and testing methodologies/standards accounting for size

Fundamental Questions:
Does nominal strength change as the specimen gets larger?

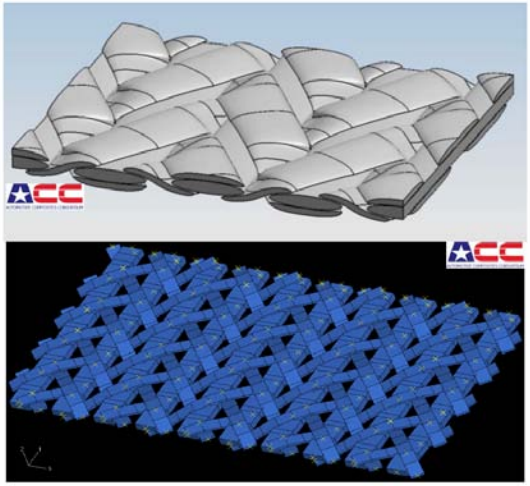




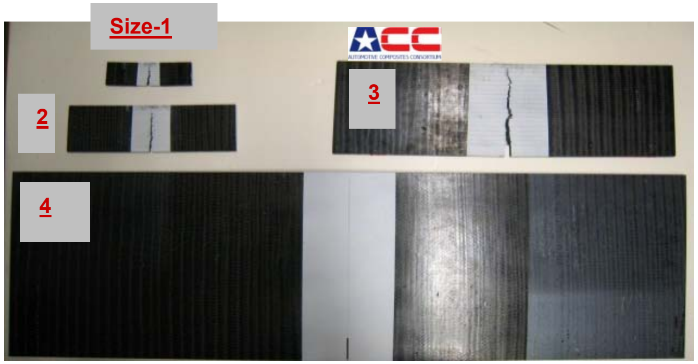
Size Effects in Textile Carbon Composites

Highlights of Sample Results (Modeling & Testing):

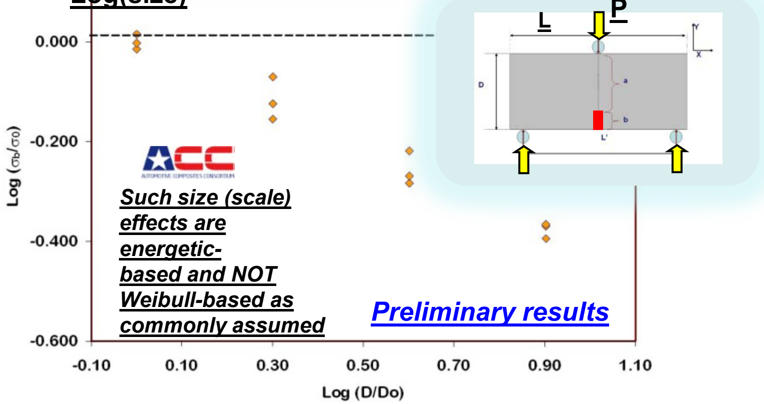
Different levels of micro-FEM/FEA of braids



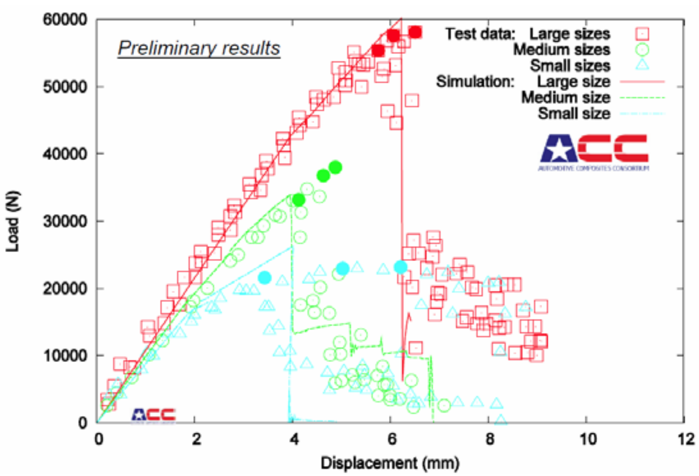
Coupons & Plaques for all 4 sizes being tested



Experimental data for Log(strength) vs Log(size)

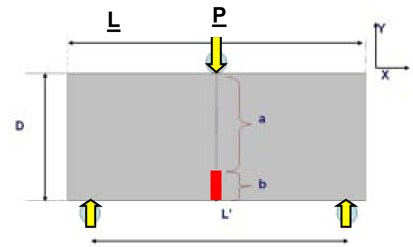


Modeling prediction vs. experimental data for different

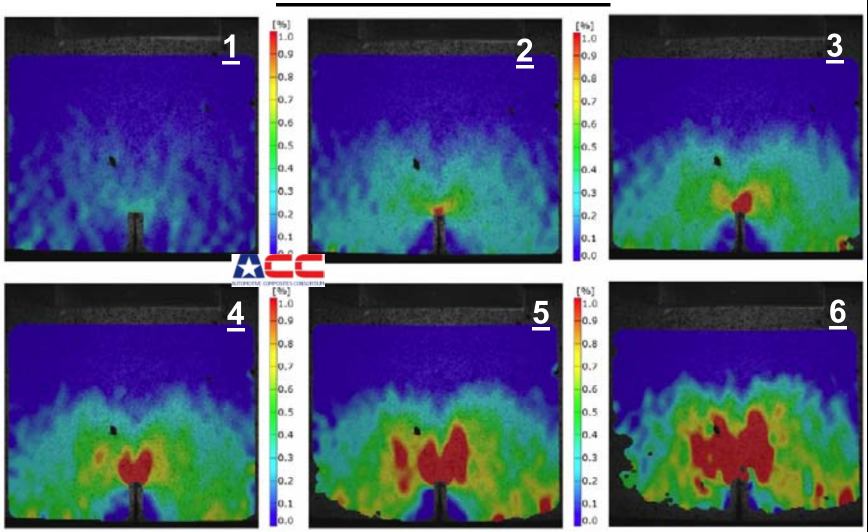


Size Effects in Textile Carbon Composites

Highlights of Sample Results (Testing):

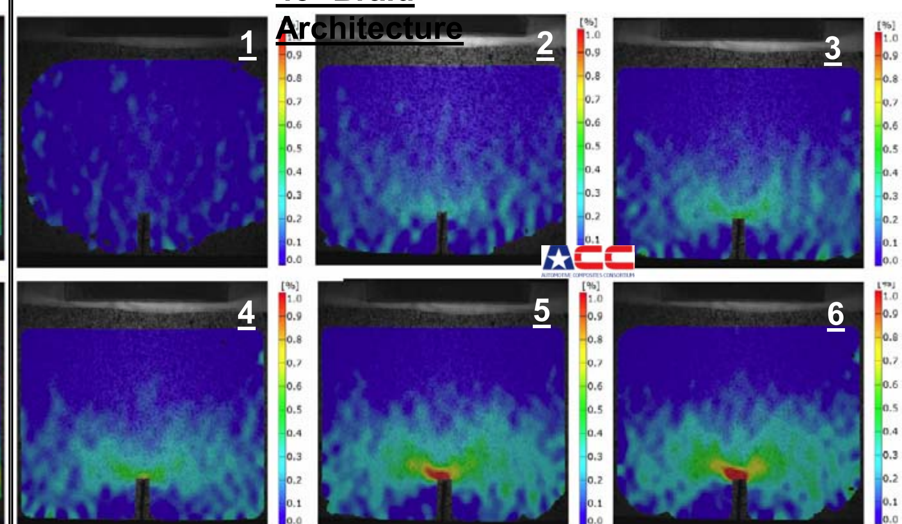


30^{o} Braid Architecture



Evolution of the deformation zone (strain field contours) near and around the initial crack (bottom mid-point of the specimen) in a
30^{o} carbon braided textile.

45^{o} Braid Architecture



Evolution of the deformation zone (strain field contours) near and around the initial crack (bottom mid-point of the specimen) in a 45^{o} carbon braided textile.

Modeling of The Manufacturing Process Induced Effects on Matrix Properties of Textile Composites

Overview:

Research Contractor: University of Michigan

Duration: 2.5 years

Budget: $521K (total)

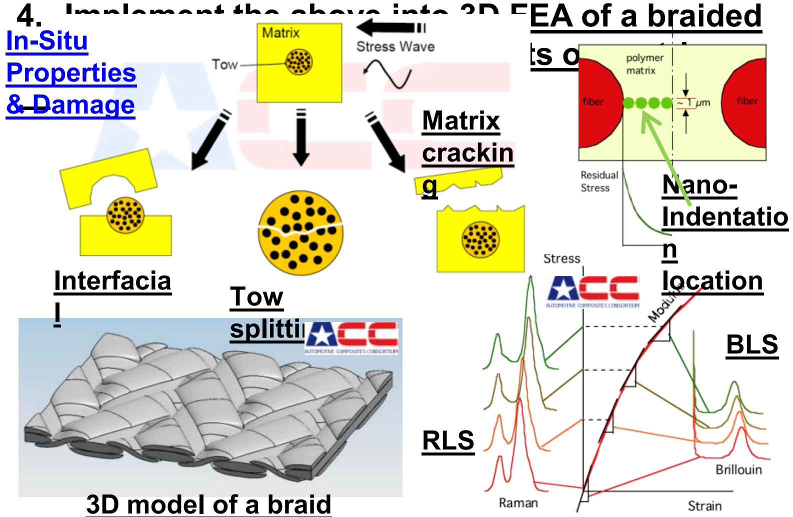
% Completion: 60% complete (on-going)

Approach:

1. Carry out an extensive nano-indentation studies to characterize the local fiber & matrix properties in different braid architectures and resin systems
2. Carry out extensive experiments using optical techniques (Raman Light & Brillouin Light Scattering—RLS & BLS) to measure evolution of thermo-micro-mechanical properties in space/time
3. Develop & validate a computational tool to model & predict *in-situ* material properties in braids
4. Implement the above into 3D FEA of a braided ... ts o...

Objectives:

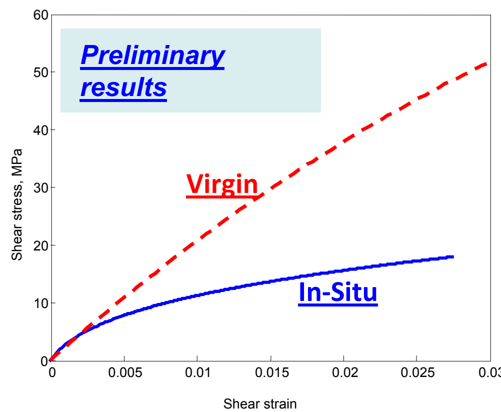
1. To extensively investigate via experimental characterization local *in-situ* properties of matrix-fiber systems in braided carbon textile composites
2. To develop an analytical and qualitative under-standing of the evolution of local properties during curing and develop a modeling capability to predict the final values of *in-situ* properties needed to characterize the mechanical response
3. To develop a comprehensive methodology that is able to quantify & robustly predict local properties prior to implementation into global FEA models



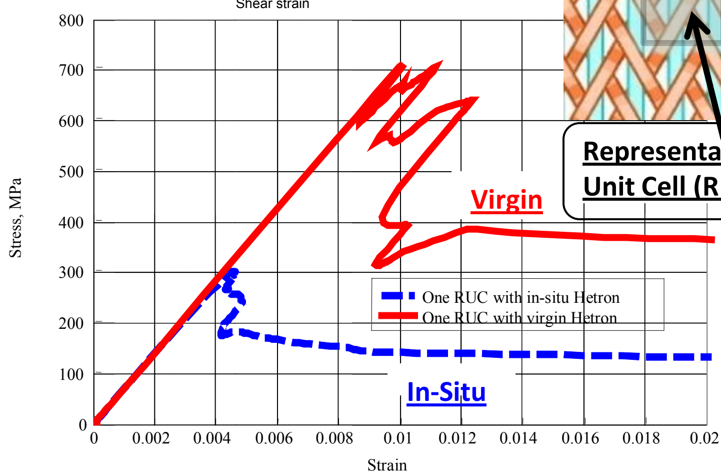
3D model of a braid

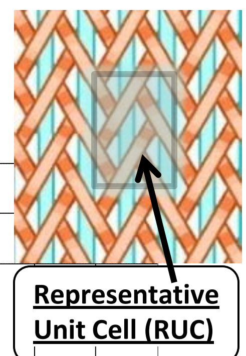
Modeling of The Manufacturing Process Induced Effects on Matrix Properties of Textile Composites

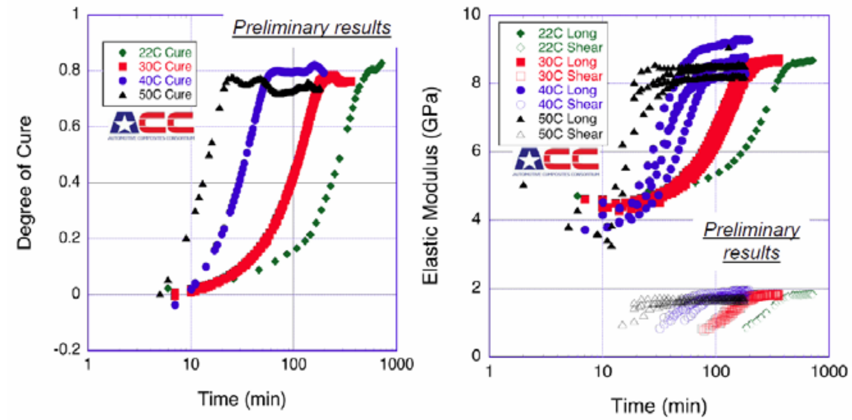
Highlights of Sample Results (Modeling & Testing):



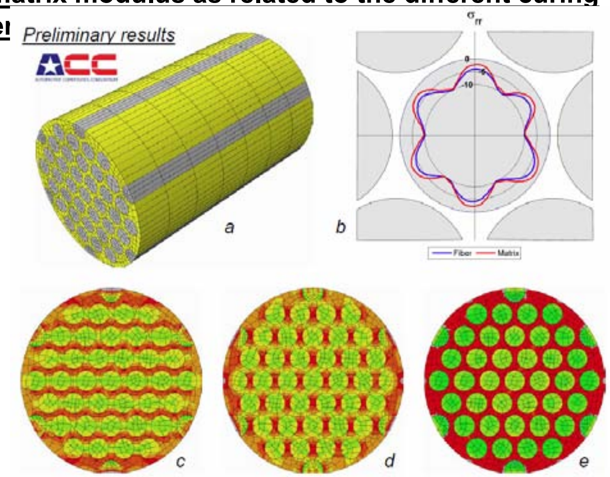
Difference in σ-ε relationship between *in-situ* vs. virgin properties (left) can result in strength variations of the braided composite at the RUC level.







Tests demonstrating some of the observed variations in the final matrix modulus as related to the different curing temper



FE analyses simulating the residual stresses in a cured tow containing carbon fibers and matrix.

ACC100 Points of Importance

- The inconspicuous perceptions of the conspicuous fact that knowledge and know-how developed for characterizing and modeling metallic structures are not all transferable to lightweight fiber-reinforced polymeric composites must be overcome.

- The constant reference by reviewers to the "aerospace industry" as having pioneered the composites field and having already characterized, modeled and predicted the full nonlinear response of lightweight composites within the crashworthiness and safety contexts is not only incomplete, but is unsupported and can be misleading. It also does not help the US automotive industry's significant efforts and challenges which are aimed at reducing vehicles' weight while meeting/ exceeding all functional and performance (strength, durability, crashworthiness & safety) requirements using advanced lightweight materials including fiber-reinforced polymeric composites.

- The cost of carbon-fiber reinforced composites (material and manufacturing) is one of the factors limiting their wide use at the current time. Further, unlike the case of high-cost aerospace composites, developing robust characterization and predictive tools for less-costly non-aerospace structural composites is a much more challenging/formidable task.

- One of the focus topics in designing lightweight automotive composites for crashworthy applications is on their abilities to absorb and manage impact energy. Such an essential requirement dictates a focus on characterizing the FULL regimes of material/structural response including the post-peak regime. Unlike many aerospace designs, this is somewhat unique to automotive designs which are required to meet all crash safety regulations for certification as well as industry and consumer-rating standards.

ACC100 Future Plans

The following is a list of the future plans that are under consideration for 2010-2012:

- **Complete the current on-going projects focused on characterizing size-effects in textiles as well as *in-situ* properties' predictions tools.**
- **Complete and deploy a state-of-the-art modeling database which contains the computational modules which will be necessary to develop and execute micromechanical models for the crush and energy absorption evolution during a crash event.**
- **Design, initiate and complete a Component Verification and Validation project in order to demonstrate the know-how (testing, modeling) developed thus far using an automotive primary-structural component (e.g., composite front-end**

Focal Project 4: Structural Automotive Components from Composite Materials (ACC007)

Libby Berger (General Motors)

John Jaranson (Ford)

Automotive Composites Consortium (ACC)

June 9, 2010

Project ID #LM021

Overview

Timeline

- Start – October 2006
- Finish- December 2014
- 45% complete (based on time)

Budget

- Total project funding
  - DOE share: $8,035K
  - Contractor share: $5,400K
- Funding received in FY09
  - $768K
- Funding for FY10
  - $863K

Barriers

- Barriers addressed
  - The cost-effective mass reduction of the passenger vehicle, with safety, performance, and recyclability;
  - Performance, reliability, and safety comparable to conventional vehicle materials;
  - Development and commercial availability of low cost structural composites, with lifecycle costs equivalent to conventional steel.

Partners

- Interactions/ collaborations
  - Multimatic
  - Continental Structural Plastics (CSP)
  - Century Tool and Gage
  - ORNL
  - U Mass Lowell
- Project leads
  - Libby Berger
  - John Jaranson

Objectives

Focal Project 4: Structural Automotive Components from Composite Materials (ACC007)

The objective of this project is to use composite materials to decrease the mass of high-volume automotive structures, at acceptable cost. The project goals are:

- **Guide, focus, and showcase the technology research of the ACC working groups.**
- **Design and fabricate structural automotive components with reduced mass and cost, and with equivalent or superior performance to existing components.**
- **Develop new composite materials and processes for the manufacture of these high volume components.**
- **Design, build, and test a composite front end, in order to evaluate the dynamic behavior models developed under ACC100**

Focal Project 4

Milestones

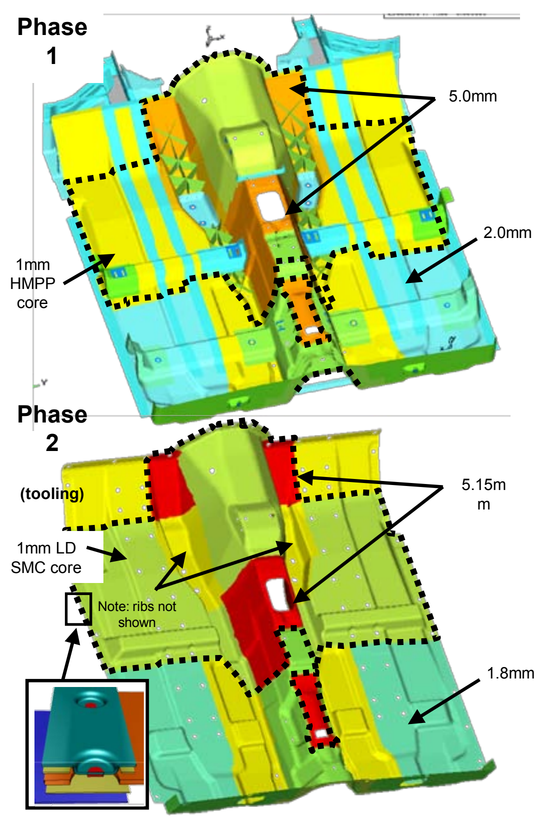
Month/ Year	
Nov 2007	Structural Composite Underbody: Selection of a Material and Process System
Mar 2010	Structural Composite Underbody: Full Design of Underbody, Including Manufacturing and Analysis Scenarios
Dec 2010	Structural Composite Underbody: Fabrication, Testing and Analysis of Underbody
	Lightweight Composite Seat: Initial Design and Structural Analysis
	Lightweight Composite Seat: Design for a Cost-effective Seat
	Lightweight Composite Seat: Fabrication and Testing of Seat
2011	Composite Front End: Determine energy management and analysis techniques to be used
2013	Composite Front End: Design, analyze, build and test representative of a vehicle front end
2014	Composite Front End: Compare analysis to experimental results

Focal Project 4

Approach

- This project targets three automotive structures, an underbody, a seat, and a composite front end, as well as the materials and processes required to produce them.
- The underbody project will design, analyze, fabricate, and test a structural composite underbody for a large rear-wheel-drive vehicle. The primary research outcomes of this project are:
  - A 2 ½ minute cycle time (100k vehicles per year, 2 shift operation)
  - Methods of joining and assembly of the underbody to the vehicle
  - Processes for fabricating oriented reinforcement within the time window
- The seat project focuses on a second row seat which will combine the functions of a seat (both with and without an integrated restraint system) and a load floor. It must fold for the load floor, save mass, and be cost competitive at volumes from 20k to 300k.
- The composite front end, which will become Focal Project 5, will be the design, build, and test of a front end module, with the goal of evaluating the various dynamic models for composite energy management that have been developed under ACC100.

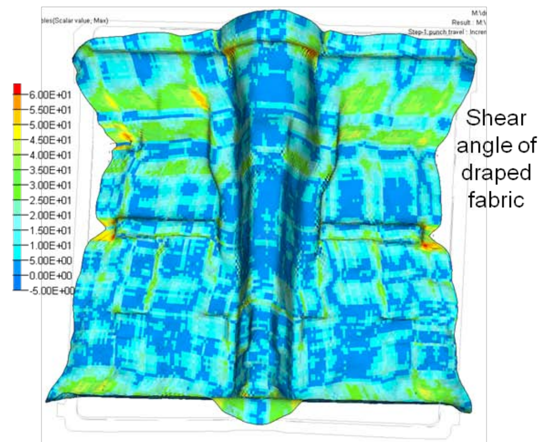
Structural Composite Underbody: Technical Accomplishments

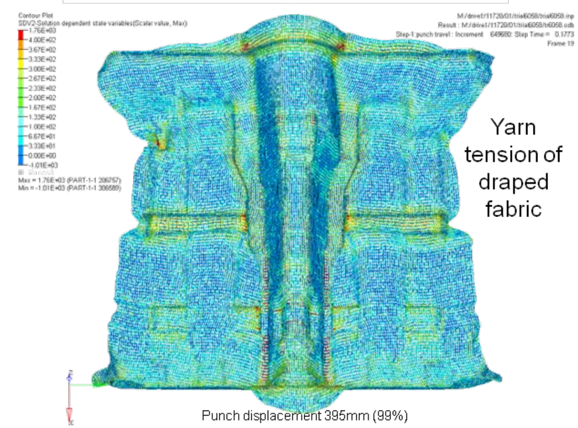


- Full design of underbody, including manufacturing and assembly scenarios
  - Refine the underbody design and thickness map, suitable for tooling
  - Glass fabric/vinyl ester SMC with low density SMC core
  - Mass savings 11.5 kg
  - Composite to steel weld bond joint (patent applied for in 2008)

Structural Composite Underbody: Technical Accomplishments

- Fabric Drape Analysis
  - Surrogate rear tub tool
    - Allowed molding trials with large, complex shape
  - Double dome tool
    - Analysis correlation with material properties and molded part
  - Full underbody
    - Shear angle
    - Yarn tension



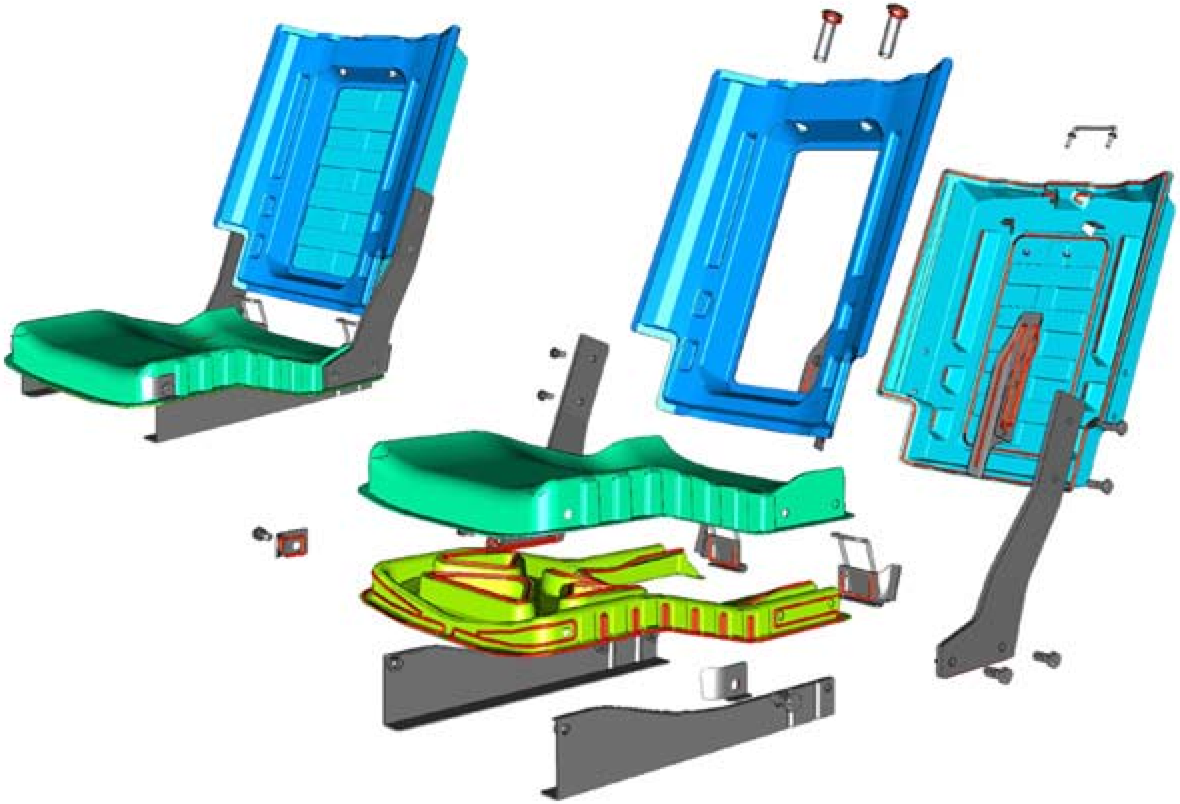


Structural Composite Underbody: Technical Accomplishments

- Initial molding trials - full underbody
  - **Demonstrate molding with fabric SMC**
  - **Load fabric preform in 40 seconds**
  - **Cure time 2.5 min**
  - **Path forward for 2.5 min cycle with 3-piece tool**

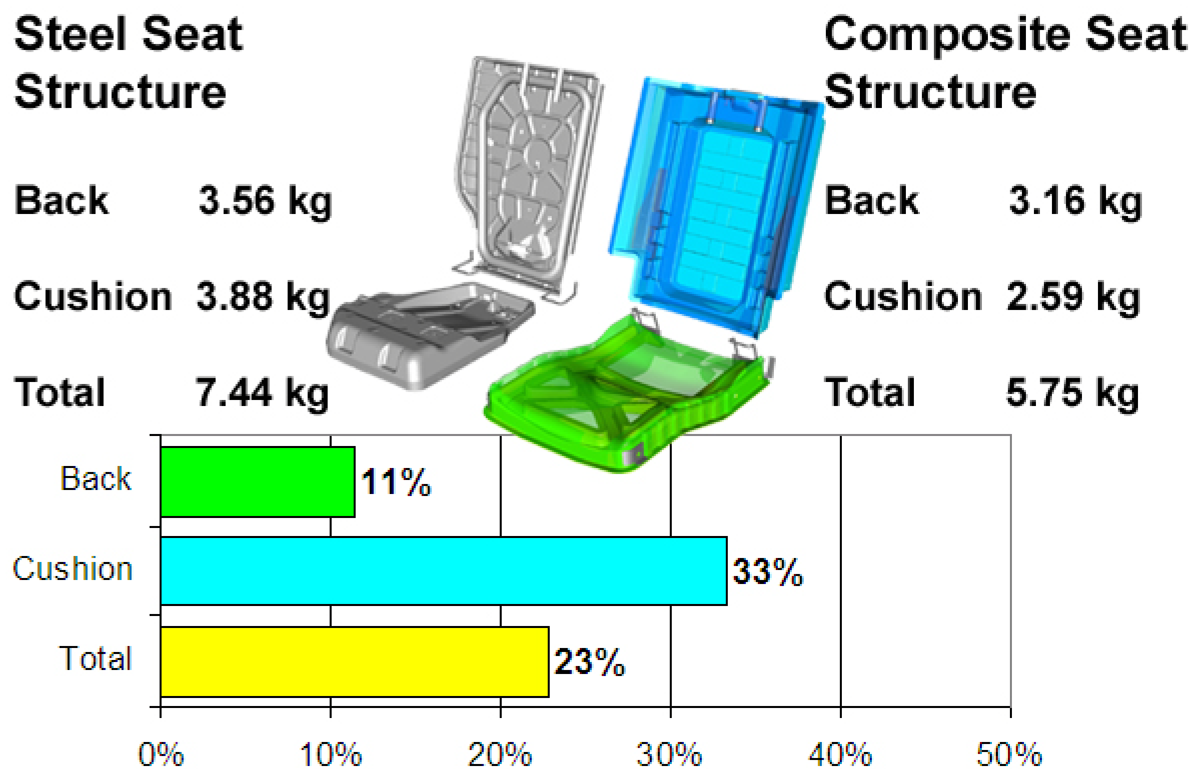
Composite Seat
Technical Accomplishments

- Completed final design of composite seat.
- Completed CAE for all loading requirements.



Composite Seat Technical Accomplishments

- Achieved a 23% weight reduction for the seat structure compared to a typical steel seat structure.



Focal Project 4: Collaborations

- **Partners**
  - Multimatic
  - Continental Structural Plastics (CSP)
  - Century Tool and Gage
  - ORNL
  - U Mass Lowell

- **Technical Transfer**
  - OEM’s to determine opportunities for future implementation

Focal Project 4: Future Efforts

1. Molding of composite underbodies will continue, with emphasis on meeting design and manufacturing scenarios.
2. The composite underbody team is currently analyzing testing scenarios for an assembled underbody structure. Molded underbodies will be assembled and tested in static and dynamic modes, with the results compared to the analysis.
3. Technical cost models of the manufacturing and assembly processes will be finished in second quarter 2010.
4. Future work for the composite seat includes repeating the cost modeling exercise with the final glass design and materials. Molding tools will be designed and built in order to manufacture the composite parts. In addition, the metal reinforcements and brackets and the foam pads will be prototyped to allow build-up of complete seats for testing. Molding trials will commence by the end of the second quarter in 2010.
5. The completed seats will then be tested for verification of the design. Detailed test plans will be developed.