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

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Automotive Composites Consortium (ACC)

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Project ID #LM046

Objectives

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

Two Efforts in ACC932 for FY11

1: Carbon Fiber Sheet Molding Compound (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.

2: Direct Compounding of Thermoplastic 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.

ACC932 Budget Overview

Total Project Funding In $K	Total Project Funding DOE	Total Project Funding Contractor	DOE Funding Received FY2011	DOE Funding FY2012
5,957	2,979	2,979	282	18

Overview – CF SMC

Timeline

- Start – May 2007
- End – December 2011
- 100% Complete

Budget

- FY11 project funding
  - DOE share $163K
  - Contractor share $163K
- FY12 project funding
  - DOE share $0
  - Contractor share $0

Barriers

- Barriers addressed
  - Technical; Fiber Compatibility and Surface Treatments, Resin Development and High Volume Manufacturability
  - Market: Fiber Cost, Inadequate Supply Base and Understanding of Automotive Requirements

Partners

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

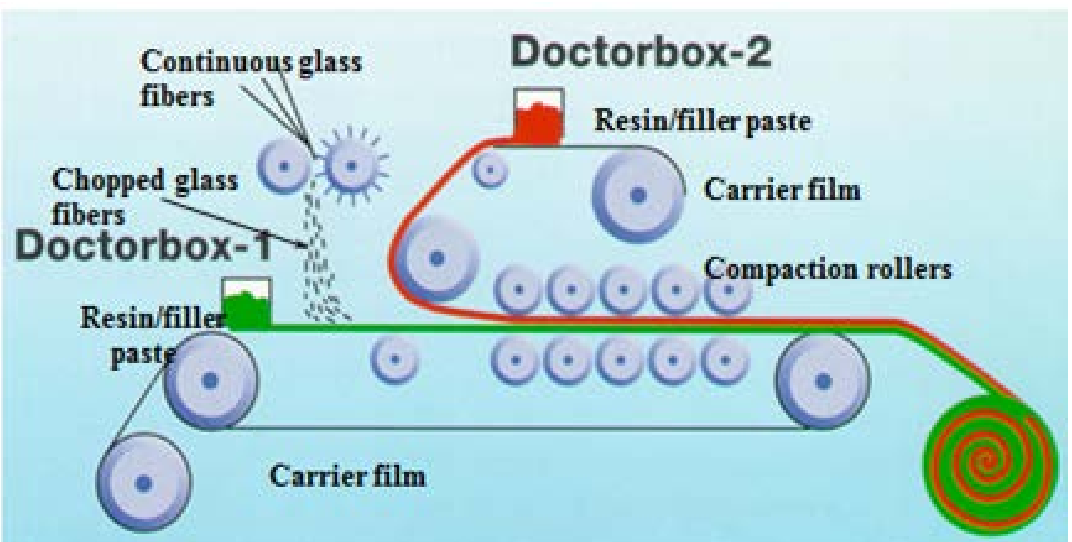
Carbon Fiber SMC

Milestones

Date	
May 2008	Installed carbon fiber SMC compounding equipment modification.
Sept 2009	Explored “air knife” to enhance de-bundling of the carbon fibers. De-tensioning the bundle seems to be a crucial element.
Dec 2010	Developed 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	Incorporated a low cost structural carbon fiber with an optimized resin system and compounding process to produce a cost effective carbon fiber SMC package.
Dec 2011	Developed and fabricated non-traditional compounding roller to open gaps in large carbon fiber bundles prior to chopping the fibers.
Dec 2011	Achieved physical property performance target with one vinylester resin (structural) and 75% of target with polyester resin (class-A) systems.
June 2012	Documentation to allow Tier-1 suppliers to use carbon fiber SMC for OEM usage.

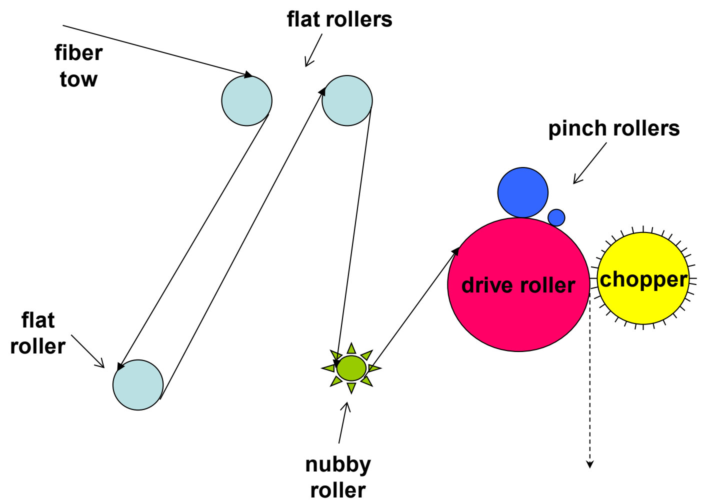
Carbon Fiber SMC – Approach

- Initiate studies with Tier-1 molder and Tier-2 resin and fiber suppliers 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.

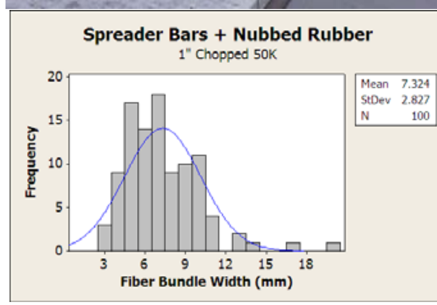


- Investigate optimizing the compounding process for enhanced consistency and cost effectiveness.
- Focus on optimizing the structural compound to enhance its appearance for visible automotive applications.

Carbon Fiber SMC – Accomplishments
Split Carbon Fibers Using Nubby Rollers



US patent application filed by ACC



	No Rollers (Standard Chopping)	4 Flat Rollers	3 Flat Rollers + 1 Rubber Nubby Roller+	2 Flat Rollers + 1 Teflon Coated Metal Nubby Roller+
Bundle Width*, Mean (mm)	8.5	15.8	7.3	3.3
Bundle Weight*, Mean (mg)	93.3	91.1	43.7	18.3
Tow Size, Equivalent	50K	50K	24K	10K
Ashland VE/PE SMC Tensile Strength (MPa)	26□	30	46	102

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

Document final report for Carbon Fiber SMC project
This project is 100% compete

Summary – Lesson Learned

1. Robust production of low cost carbon fiber SMC requires that choppers be redesigned (air, splitters, etc.), to achieve optimal processing parameters for a system with best fiber-resin compatibility.
2. Large tow carbon fibers can be de-bundled inexpensively by air chopper filamentizatioin or mechanical splitting. Zoltek 50K fiber and Ashland VE/PE resin produced SMC with the target 150 MPa tensile strength.

Documentation of Results

1. Charles Knakal, CS Wang, Jeffery S. Dahl and Bhavesh Shah, “Carbon Fiber SMC”, Automotive Composites Consortium Technical Report, ACC932-14, August 19, 2011.

Overview – Direct Compounding of Structural Thermoplastic Composites

Timeline

- Start – March 2009
- End – December 2011
- 100% Complete

Budget

- FY11 project funding
  - DOE share $119K
  - Contractor share $119K
- FY12 project funding
  - DOE share $18K
  - Contractor share $18K

Barriers

- Barriers addressed
  - Technical; Process feasibility, material performance and scalability for manufacturing

Partners

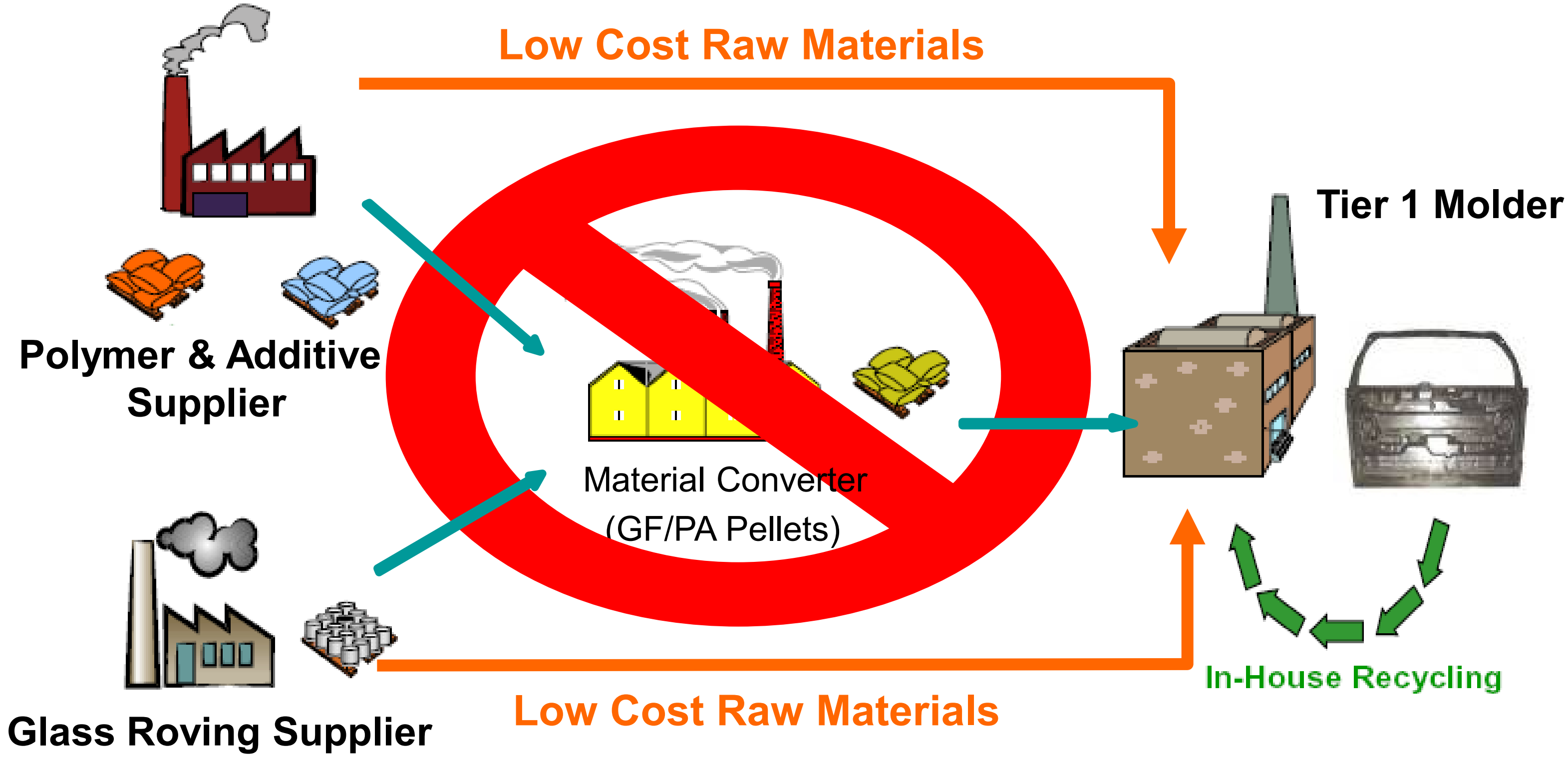
- Continental Structural Plastics, a Tier One supplier
- DuPont, BASF, PPG, and
- University of Western Ontario

Affordable Vehicle Weight Reduction through Direct Compounding

Month/ Year	**2011 & 2012 Milestones**
3/2011 – 6/2011	Additive DOE for Direct Long Fiber Thermoplastic (D-LFT) Compounding with Four (4) Factors each at Two (2) Levels
9/2011 – 12/2011	Compounding trials investigated the effect of compounder screw element design and configuration on constituent dispersion, distribution and fiber length attrition. Full scale manufacturing demonstration study completed.
6/2012	Completed documentation of project results and SAMPE conference paper

Affordable Vehicle Weight Reduction through Direct Compounding – Approach

Material Supply Chain Options for Thermoplastics Composites



Affordable Vehicle Weight Reduction through Direct Compounding

Approach

From Jan to Dec 2011 **four** distinct process studies determined the feasibility of applying direct compounding method (D-LFT) to structural high temperature thermoplastics (reinforced with either glass or carbon fiber)

Study One: Compression Molding vs. Injection Molding

Determine material performance benefits of processing using direct compounding with compression molding vs. using direct compounding with injection molding (mechanical testing completed since 2011 AMR).

Study Two: Additive Packages

Experimental program to determine impact of additive systems on long-term heat ageing of direct compounded materials.

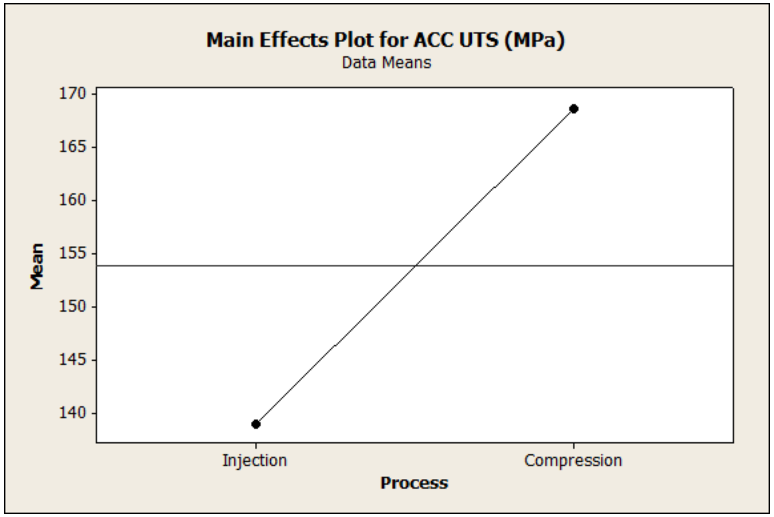
Study Three: Extruder Mixing Screw Design

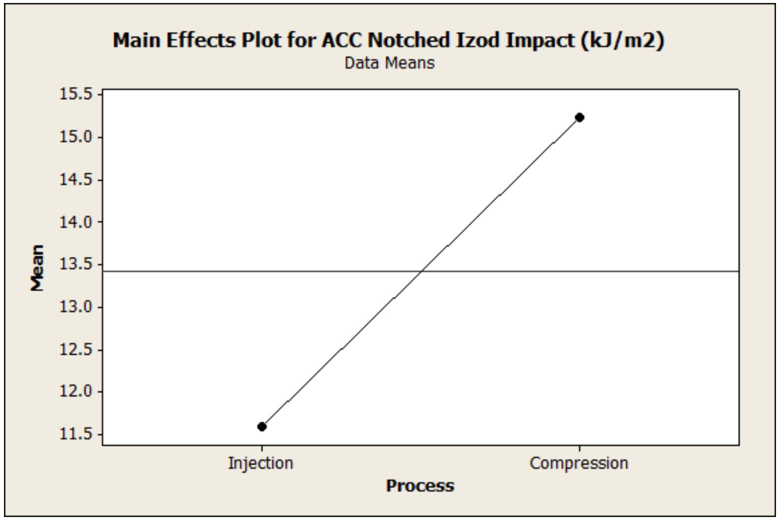
Extruder process setup and effect of twin screw design on the fiber attrition and resultant properties of glass and carbon composite panels.

Study Four: Large Part Demonstration

Scaling studies to demonstrate feasibility of using the direct compounding method on a full scale complex 3-D geometry.

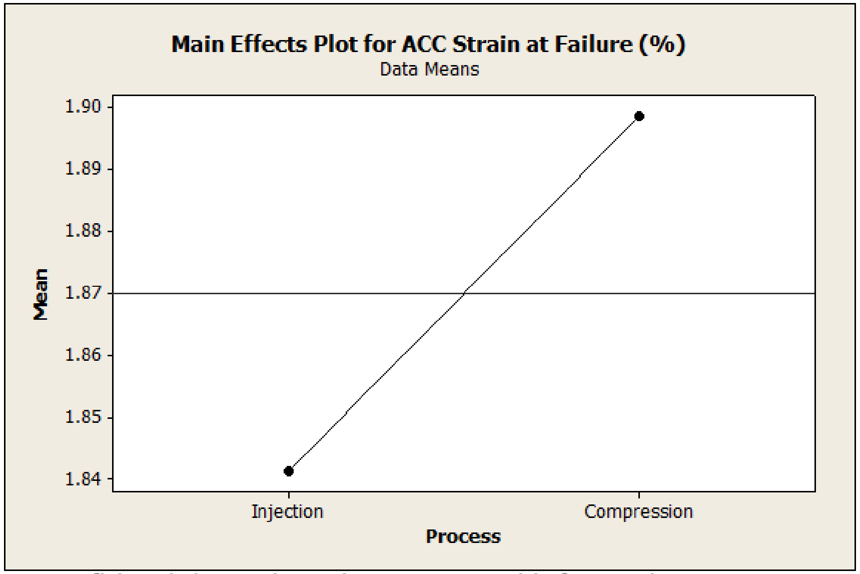
Affordable Vehicle Weight Reduction through Direct Compounding – Accomplishments





Study #1: Compression versus Injection

- Study indicated both process methods were viable.
- Mechanical properties of compression molded samples were observed to be typically higher than injection molded.
- Properties matched those processed using pre-compounded material systems.

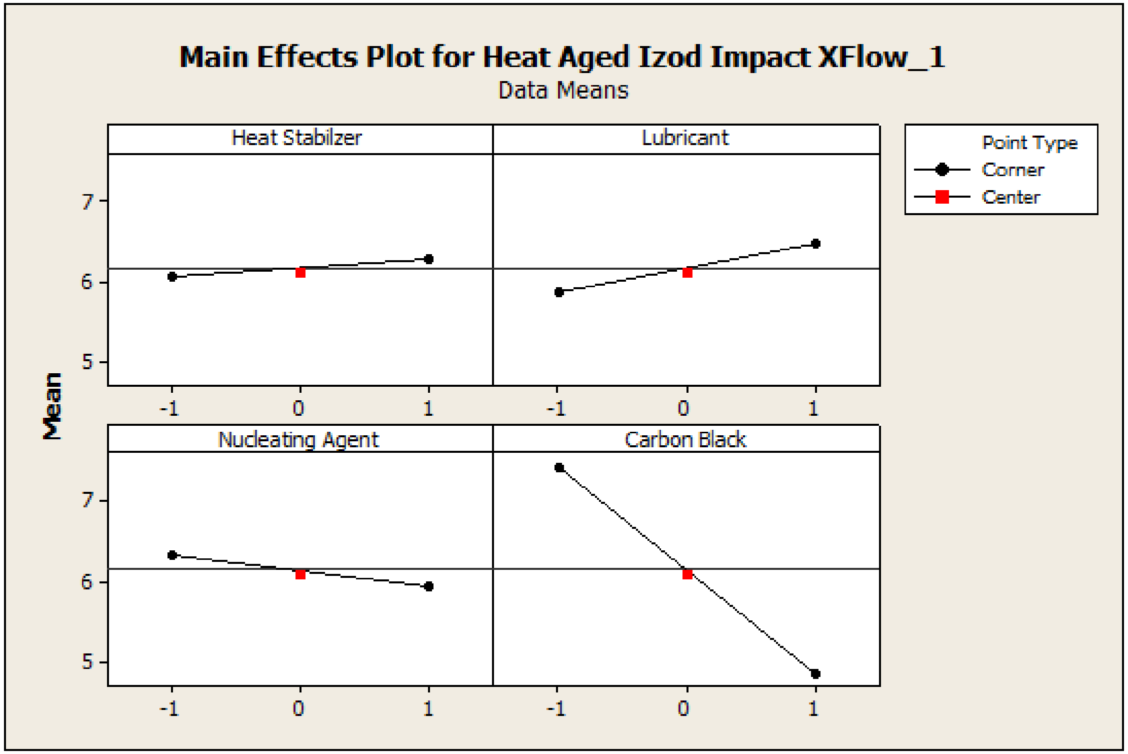


Affordable Vehicle Weight Reduction through Direct Compounding – Accomplishments

Study #2: Effect of Polymer Additives

- Additive level designed experiment

FACTOR	LOW	HIGH
Heat Stabilizer	-1	1
Lubricant	-1	1
Nucleating Agent	-1	1
Carbon Black	-1	1



Affordable Vehicle Weight Reduction through Direct Compounding – Accomplishments

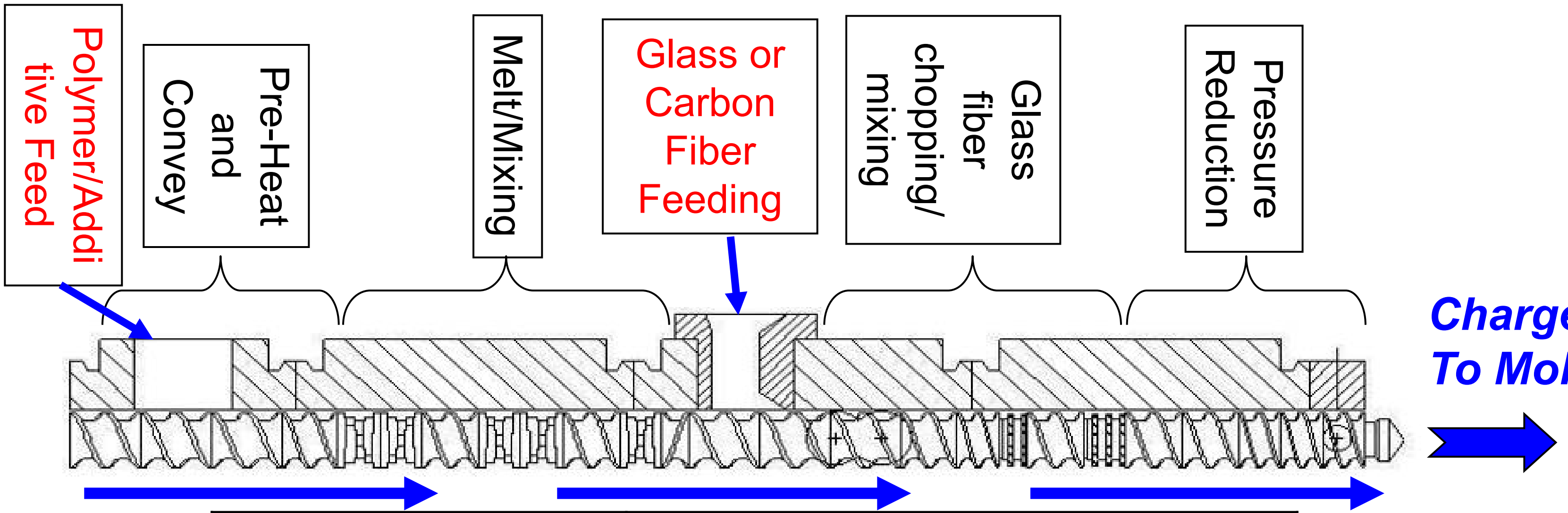
Study #3: Extruder Mixing Screw Design DOE

- Investigate effect of mixing extruder screw element selection on mechanical properties of molded panels.
- Investigate both glass and carbon fiber

FACTOR	LEVELS			
Fiber Type	Glass		Carbon	
Screw Speed (RPM)	75		150	
Screw Configuration (Zones 2 and 3)	1	2	3	4
Screw Zone 1	2x GFA-2-30-30		GFA-2-60-60	

Affordable Vehicle Weight Reduction through Direct Compounding – Accomplishments

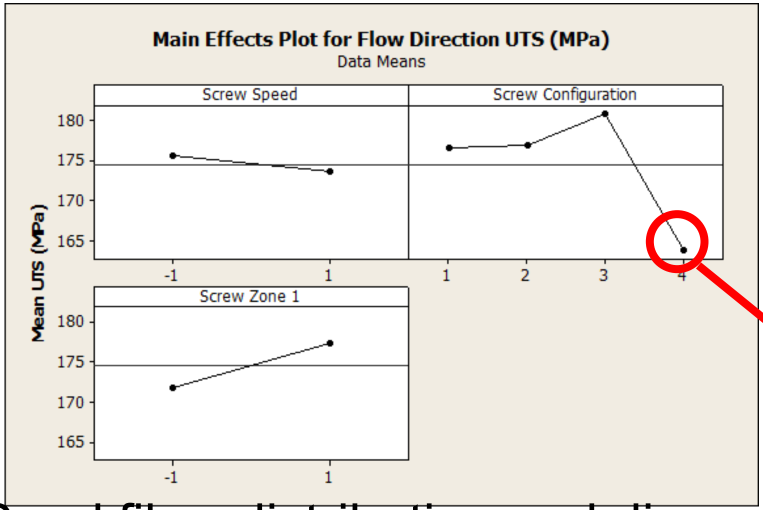
Study #3: Extruder Mixing Screw Design DOE



FACTOR	LEVELS			
Fiber Type	Glass		Carbon	
Screw Speed (RPM)	75		150	
Screw Configuration	1	2	3	4
Screw Zone 1	2x GFA-2-30-30		GFA-2-60-60	

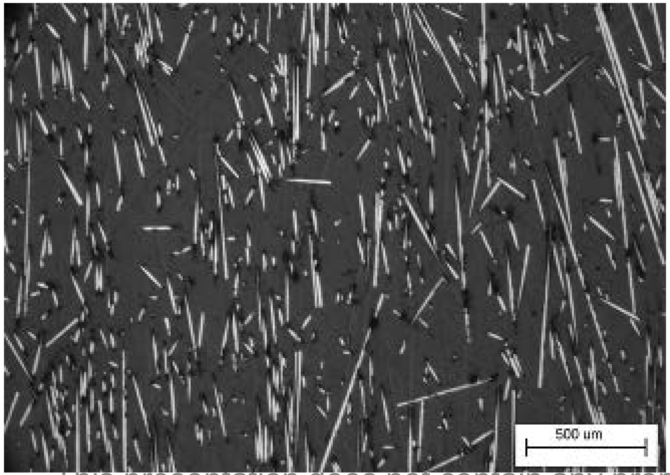
Affordable Vehicle Weight Reduction through Direct Compounding – Accomplishments

PA66/Carbon Fiber Ultimate Tensile Strength

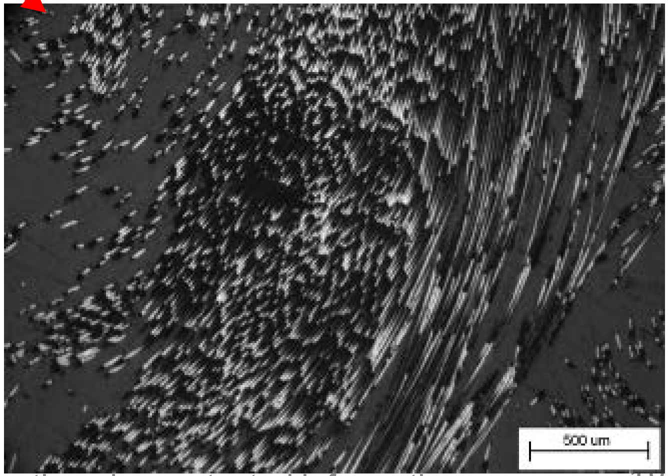


- Reduction in strength observed with screw configuration #4 is due to inadequate fiber dispersion and wet out

(Good fiber distribution and dispersion)



(Poor fiber de-bundling)



Affordable Vehicle Weight Reduction through Direct Compounding – Accomplishments

Study #4: Large Part Processing Demonstration

- Investigate mixing extruder screw parameters on resultant performance
- Demonstrate feasibility of scaling D-LFT process for molding of a large complex 3-D part, Ford Galaxy grill opening reinforcement (GOR)
- Mechanical testing completed in Q2 FY12

Affordable Vehicle Weight Reduction through Direct Compounding

Documentation of Results

1. Patrick Blanchard, Jeffrey S. Dahl and Daniel Q. Houston, "Extrusion-Compression Molding of Polyamide-Glass Fiber Composites using Pre-Compounded Pellets," Automotive Composites Consortium Technical Report, TR 09-02.
2. Jeffrey S. Dahl and Patrick J. Blanchard, "Polyamide Formulation Development: Twin-Screw Compounding and Mechanical Performance of a Short Glass Fiber Reinforced Polyamide 66 Based Composite," Automotive Composites Consortium Technical Report, TR 10-01.
3. William Rodgers, Jeffrey S. Dahl, Patrick J. Blanchard, "In-Line Stabilization of Direct Long Fiber Thermoplastic Composites: Short Fiber Analogue Investigations", Automotive Composites Consortium Technical Report, TR ACC932-15.
4. Jeffrey S. Dahl, Patrick J. Blanchard and William Rodgers, "Fraunhofer ICT Trials Work Package 2: Investigation into the Direct Compounding and Compression Molding of Glass Fiber Reinforced Polyamide 66 Composites", Automotive Composites Consortium Technical Report, TR ACC932-16.
5. Jeffrey S. Dahl, Patrick J. Blanchard and William Rodgers, "Fraunhofer ICT Trials Work Package 4:
6. The Effect of Mixing Extruder Processing Parameters on the Performance of a Carbon Fiber Reinforced Polyamide 66 Composite", Automotive Composites Consortium Technical Report, TR ACC932-17.
7. Jeffrey S. Dahl, Patrick J. Blanchard and William Rodgers, "Direct Compounding of a Carbon Fiber Reinforced Polyamide 66 Composite", SAMPE 2012, May 2012, Baltimore, MD.

Summary

- Feasibility of using direct compounding method on polyamide 66 formulations has been demonstrated
- A quantitative study showing the relative merits of using direct compounding with Injection Molding and Compression Molding has been completed.
- Equivalent or greater performance has been demonstrated using direct compounding vs. conventional pelletized materials.
- Preliminary work performed on carbon fiber reinforced PA66 show flexibility of process to accommodate mixed fiber types.
- Process scale up of direct compounding demonstrated through compression molding of a front end GOR.