Carbon Composites

Entering Mainstream Automotive

Jackie Rehkopf, PhD
NHTSA Mass-Size-Safety Symposium
May. 13-14, 2013
• Introduction to Plasan Carbon Composites
• Opportunities for CFRP in Mainstream Automotive
• Requirements for Efficient Production of CFRP
• Evolution from Niche to Mainstream Automotive via Technology Development
PLASAN’S INTERNATIONAL OPERATION
Michigan Facilities

- 24,000 square foot Facility
  - \( \frac{1}{2} \) Manufacturing Space
- Scale-up Facility for New Technology
  - Production-Representative
- Focus on Market Penetration
NEW MFG FACILITY IN WALKER, MI

- 197,000 square feet Manufacturing
- Incentives from the Michigan Economic Development Corporation (MEDC)
- > $20M in Capital Investment
- > 200 New Jobs
- Geared to Higher-Volume Production
- Incorporates Plasan’s New Manufacturing Methods
- Plasan’s CFRP Processing Breakthroughs

- Supports 30K-50K Vehicles per Year
- Future Improvements to Reach 100K
**CORVETTE SPECIALTY MODEL: ZR1**

- **Fender:** 4 lbs.
- **Hood:** 12 lbs.
- **Splitter:** 1 lb.
- **Roof:** 13 lbs.
- **Roof Bow Cover:** 3 lbs.
- **Rocker:** 1 lb.
Hood Fender Assembly: 38 lbs.

Roof Assembly: 27 lbs.

Lift Gate Assembly: 9 lbs.

CF components reduced the car weight over 100 pounds over previous model.

44% of exterior components produced in carbon fiber.
Opportunities for CFCs in Mid-Volume Vehicles
Key Drivers for Improved Fuel Economy

- Government: CAFE Regulations
  Energy Independence Initiatives
- Consumer: High Gasoline Prices
  Environmental Concerns

Affected Vehicle Aspects
- Drive trains / Propulsion Systems
- Aerodynamics
- Parasitic Losses
- Mass Reduction
CARBON FIBER ADVANTAGES

- Low Density

% Lighter than:

<table>
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<th>Material</th>
<th>Steel</th>
<th>Aluminum</th>
<th>Mg Alloy</th>
<th>SMC</th>
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<tr>
<td></td>
<td>70%-80%</td>
<td>30%-40%</td>
<td>30%-35%</td>
<td>40%-50%</td>
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- Excellent Strength & Stiffness to Weight Ratios
- Excellent Corrosion resistance
- Thermal Stability & Moisture Stability
- Improved NVH characteristics
- Design Flexibility
- Part Consolidation
- Short Lead Times
- Low Capital Cost
CONSUMER BENEFITS

- Improved Structural Rigidity
  - E.g. Roof - Increased Torsional Rigidity in the Vehicle

- Lighter Weight
  - Lower Center of Gravity (depending on component, e.g. Roof, Hood)
  - Improved Vehicle Dynamics
  - Improved Power to Weight Ratio

- Improved Corrosion Resistance
Both Hybrids & CUVs have significant mass reduction needs (Battery Pack & Large Vehicle Size)
CFC ENTRY INTO AUTOMOTIVE

- Offshoot from Aerospace
- Autoclave Process
- Process Attributes
  - High Quality Parts
- Process Limitations
  - Slow Cure Cycle
  - Thermally Inefficient
  - N2 Atmosphere
  - Labor Intensive
  - Supports Low Volumes
KEY REQUIREMENTS FOR EFFICIENT PRODUCTION

• > 50K Units per Year
• Cost-Effective
  – Less Than 3-4 X Cost of Lightweight Metal
• Low Void Content, High Surface Quality
• Readily Fastened/Assembled to Other Components
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Source: Good Car Bad Car

June 2012 YTD Top 260 Best-Selling Vehicles In America - Every Vehicle Ranked
**Plasan’s Pressure Press Technology**

- Class A & Structural Parts
- 1 Coat Primer
- Production Volumes of 30K-100K per Year
- Development Continues to Further Reduce Cycle Time

**Faster Cycle AND Improved Surface Quality**
Pressure Press Technology

Sub 20-Minute Production

1- Kit Cut
2- Lay-up
3- Press
4- Trim
5- Inner Sub-Assembly & Outer/Inner Bonding
6- Finishing
7- Prime

Balanced Process Cycle Time
For High Volume Automotive

Pressure Press < 20 minute

Same Material System
Same End Properties
PRESSURE PRESS v AUTOCLAVE

Pressure Press Economies

- Energy
- Consumables
- Labor
- Tool Transfer
- Part Teardown

- Conventional Autoclave
- Pressure Press
Customer/Business Value

Near Term Business Development

- Autoclave 90 min cycle
- Pressure Press 17 min cycle
- RTM Structures

Medium Term BD

- 7 min cycle
- New Resin Matrices

Long Term BD

- Thermoplastic 2 min cycle
- Alternative based Carbon Fibers

Out of Autoclave Technology
TECHNOLOGY DEVELOPMENTS FOR 100K +

- Advanced Mold Tooling to Reduce Cycle Time
- Laser Placement for Localized Thickness Variations
- Water Jet Trimming for Level Process Flow
- Automated Tape Lay
- Advanced Resin Development
- Automated Etching for Paint Preparation
- Pre-Forming
- RTM Molding
BUSINESS DEVELOPMENTS FOR 100K +

- Just-In-Time Material Supply
- Reduce Time & Distance from Material Source to CFC Mfg
- Minimize Material Supply Risk via Multiple Qualified Sources
- Lead Qualification Advancements as Technologies Develop
- Expand Mfg Process & Material Portfolios for Customers
- Expand CFC Design & Analysis Tools
Cascading Technology From Niche to Mainstream
Technologies in the SRT Viper Hood Assembly

- Large Complex Clamshell Geometry
  - Up to 3000 vehicle sets / year
- Textured surface on B-side of Outer Panel
- Exposed Weave Inner Panel
- Integrated Mounting Points using riv-nuts and studs on inner hood.
- Meets Structural Requirements through Local Section Thicknesses
TECHNOLOGIES IN THE SRT VIPER ROOF ASSEMBLY

- Key Structural Component of the Vehicle - Meets Roof Crush
- Layup Thickness & Orientation Custom Tuned to Meet Various Part Requirements
- CAE Permits Kits & Work Instructions Developed Before Tools Arrive
- CAD-Driven Laser Placement System Ensures Accurate Layup
CARBON FIBER COMPOSITE STRATEGY

• Engage & Collaborate with OEM Early in Design Stage

• Combine Several CFC Advantages:
  – Mass Reduction
  – Increased Stiffness and/or Strength
  – Part Consolidation
  – Design Flexibility /Aerodynamics
  – Safety – Pedestrian Impact and Others
  – Improved NVH

• Assess Cost from a Comprehensive Systems Model
  – Evaluate Cost Across Development, Manufacturing & Life Cycle
**SYSTEM APPROACH TO EVALUATE COST**

- **Value-Add**
  - Permits add’l content
  - Consumer delight

**Central Hub:**
- Reduced Supply Chain Cost
- Reduced Warranty Costs
- Lower Parasitic Power Demand
- Reduced Capital Costs
- Mass Reduction
- Part Consolidation
THE BIG COST FACTORS

- Lower Capital Costs for CFRP vs SMC or Sheet Metal
- Finished Assembly Costs Dramatically Reduced Via Continuous Development:
  - 2008-2012, $/lb of a bonded, finished prepreg assembly ↓ 39%
Integration of software tools and composite part design practices leads to improvements in throughout a company.

R&D Quoting Prototyping PPAP Manufacturing
**Material Models Database**

- Production & Non-Production Materials Kept Separate
- Relevant Composite Info Included
- FEA Material Cards Quickly Added
- Shared Material Library

![Material Models Database Interface](image)
SANDBOX FOR NEW DESIGN TECHNIQUES

- Easily Substitute Production Materials for Latest Supplier Offerings
- Test Producibility of New Layup & Ply Design Techniques Without Using Material, Tooling or Operators
- Roll Width – ↓ Ply Count – ↓ Cycle Time – ↑ Production Volume
Virtual Analysis of Ply Structures Lead to Fewer Physical Prototypes
Quick Design Feedback to Customers

- Effectively Communicate Design Constraints & Limitations
- Easily Export FEA Models with Material Definitions
- Show Joint Construction & Nominal Thickness with Cross Sections
**Quick and Reliable Kit Design**

- Example Part: *Old Way = 16 days*  *New Way = 6.5 days*
- Eng’g Experience & Judgment Confirmed by Quantified Producibility Data
- Areas Prone to Bridging or Wrinkling Identified & Addressed Prior to Build
**Class 1 Estimation:**
30 minutes with PLM (4 hours w/o PLM)
IMPROVED QUALITY CONTROLS

- Engineering Change Requests Justified by Producibility Simulations
- Flawed Parts can be Inspected on a CMM Generating a Point Cloud
- Digital Flaw and Scrap Tracking Allows Better Prediction of Scrap Parts
• Repetitive Operator Actions Accounted for by Revisions to Kit Designs
• Darts and Alignment Features Incorporated into Standard Kits
IMPACTS OF DESIGN CHANGES ON PART PRICE

- Material Prices can be Directly Linked in a Material Model
- Changes in Part Design or Mfg Efficiency Tracked & Understood
CFRP IN MAINSTREAM AUTOMOTIVE - Challenges

Successful Implementation

System Cost
Cycle Time
Assembly to Vehicle

Predicting Behaviour
Evaluating Behaviour

DE-EE0005397
**Composite Processing**

- Processing a Composite Structure is Significant Cost / Risk
- Material Equivalency Between Structure and Test Panels Essential
- Changes in Production Often Desired / Required
  - Design, Tooling, Layup, Local Thickness, Material Composition

**The Science of the Process**

\[
\text{Process} \quad \rightarrow \quad \text{Microstructure} \quad \rightarrow \quad \text{Properties} \\
(\text{Micro- Meso- Macro-})
\]

- Gas Transport
- Thermo-Chemical
- Flow-Compaction
- Stress-Deformation

**Model the Composite Process** \(\rightarrow\) to Predict Properties
C7 CORVETTE STINGRAY

Pressure Press Process
17 minute Button-to-Button Cycle
Same Prepreg as the Corvette ZR01 Roof

**Roof**
- Painted or Exposed Weave
- 1.2 mm nominal

**Hood**
- Hot-Bonded Inner & Outer
- Each 1.2 mm nominal
The Future for Automotive CFCs

- Variety of Material Constituents, Architectures, Processes
- Material System + Process Are Linked → Part Performance
- Part Performance Can Be Achieved Multiple Ways
- Factors to Consider: System Cost
  - Part-to-Part Cycle Time
  - Vehicle Assembly
  - Capital Infrastructure/Investment
  - Life Cycle

*The Material & Process Selected for a Component Will Depend on Performance & Business Case*
Questions & Comments?