Dynamic Fluid Compression Molding
A new process for composite mass-production

March 2016
Presentation Contents

1. Composites in mass production
2. Structural composite processing
3. Dynamic Fluid Compression Molding
   • New DFCM process
   • Part quality
   • Industrial fiber processing
4. About HUNTSMAN
5. Summary
Automotive structural composites

The recent growth in structural composites for automotive applications is driving innovation in both materials and processes.
Composites in Mass Production
Composite properties versus metals

• Composites display outstanding strength / stiffness-to-weight ratio compared to metals
Composites in Mass Production

Composite applications

• Increased usage of composite materials driven principally by **light weight**
• Traditional high-volume composite applications dominated by SMC/ BMC → relatively low mechanical performance
• Current trend towards high-performance structural composites; particularly **carbon fiber composites**

**Potential applications for mass-produced structural composites**

• Automotive: cars, trucks
• Public transport: buses, trams, trains
• Electronic/ electrical housings: laptops, phones
• Construction
• Sporting goods
Composites in Mass Production
Araldite® Solutions - Case Histories

BMW M3 Roof Parts with ARALDITE® XB 3523 / XB 3458

**Benefits**
- Low weight, high stiffness and high dimensional stability
- Fashion / aesthetics due to 'carbon look'
- Class 'A' finish
- Low shrinkage

Lamborghini Aventador LP700-4’s Chassis with ARALDITE® XB 3518 / ARADUR® 22962

**Benefits**
- Low viscosity during injection
- Sufficient pot life
- Low shrinkage (surface quality)
- High mechanical properties (good balance Tg / toughness)
- Good hot / wet properties

BMW i3 Life Cell  with ARALDITE® LY 3585 / XB 3458

**Benefits**
- Fast curing
- Versatile for RTM and compression molding
- Low water pick up
- High mechanical performance
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Structural Composite Processing
Processes for mass production

- New processes required to meet needs of mass production
- Huntsman has developed new 'DFCM' process enabling both speed and part complexity
Structural Composite Processing
Process comparison

- Wet compression molding (WCM) is the fastest industrial-scale composite molding process currently available.
- Curing with WCM is typically faster than HP-RTM since no latency is required for resin injection.
- However, part quality of WCM process is usually inferior to injection processes, with poor surface quality and voids/porosity.

State-of-art HP-RTM

Preforming → Preform insert → Mold closure → Vacuum → Injection → Cure → Demold
Mold and press occupation time: 3-4 min

Wet Compression Molding

Preforming (not needed for simple parts) → Wet Fabric insert → Mold closure → Cure → Demold → Cooling Jig
Mold and press occupation time: 1-2 min
Structural Composite Processing
Wet compression molding

Standard wet compression molding
- Simple process with resin overflows
- Limited to flat parts
- Voids/ porosity in finished part

New DFCM process
- Uses vacuum and mold pressure
- Higher part complexity possible
- Produces 'RTM-like' quality
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Dynamic Fluid Compression Molding (DFCM) process

- New process developed to combine speed of WCM with quality of HP-RTM
- Combines vacuum and dynamic mold pressure to achieve void-free impregnation
- Pressure enables rapid fiber impregnation, even of deep-draw areas
- Higher part complexity possible compared to standard WCM
- Lower mold pressure/press force than HP-RTM or standard WCM
- Typically only ~30 bar pressure for high-quality parts
- Industrial demonstrator made with fully integrated mold & press (TRL 5/6)

Cross section of industrial demonstrator part
Dynamic Fluid Compression Molding
Process benefits

**DFCM benefits versus standard WCM**

- Part quality: near zero void content
- Robust process: consistent quality
- Higher part complexity possible
- Near net-shape part
- Lower pressure = lower investment
- Little resin/ fiber wastage

**DFCM benefits versus HP-RTM**

- Faster process: reduced press cycle
- Higher fiber content: up to 67%
- Fiber preform less critical
- No fiber movement (fiber wash)
- Lower pressure = lower investment
Dynamic Fluid Compression Molding
New fast-cure ARALDITE® epoxy technology

- New ARALDITE® technology enables a press cycle-time of only 1 minute

<table>
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<tr>
<th>Resin: ARALDITE® LY 3031</th>
<th>100 parts</th>
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<td>Hardener: ARADUR® 3032</td>
<td>21 parts</td>
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<table>
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<tr>
<th>Internal release agent</th>
<th>Standard</th>
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<tr>
<td>Cure (1)</td>
<td>s</td>
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<td>45 s</td>
<td>30 s</td>
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<tr>
<td>DFCM cycle time (2)</td>
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<td>75 s</td>
<td>60 s</td>
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<th>Carbon fiber composite 2mm plate</th>
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<td>Visual aspect</td>
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<tr>
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<tr>
<td>Charpy impact resistance</td>
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(1) Cure time when press fully closed, (2) Total press occupation time including closure + opening
Dynamic Fluid Compression Molding

Process overview

60s
Dynamic Fluid Compression Moulding

Part quality

DFCM part made in 1 minute with ARALDITE® 3031 / ARADUR® 3032

Standard WCM Vf = 50%
HP-RTM Vf = 50%
DFCM part Vf = 52%
Dynamic Fluid Compression Molding

Industrial fibers

- Recent work shows that DFCM is effective even with heavy, industrial-grade fabrics
- Plate produced in 1-minute at 140°C using industrial 960gsm carbon fabric made with 50K fiber tows
- Void-free laminate: fiber volume fraction $V_f = 53\%$

Plate made with 960gsm PX35 TW 0960 woven fabric using PANEX®35 50K carbon fiber

PANEX® is a registered trademark of Zoltek Corporation
Dynamic Fluid Compression Molding

Fiber content

- Fiber volume content of HP-RTM normally limited to around 50% due to injection permeability
- DFCM enables fiber volume content above 60% without change of process
- Porosity-free laminates up to 67% FVC made with standard DFCM process → equivalent to autoclave prepreg quality!

DFCM part Vf = 67% X50

DFCM part Vf = 67% X500
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Huntsman Corporation

We are a global manufacturer and marketer of differentiated chemical products that improve the quality of life for people around the world.
### Huntsman Corporation
Our Business Divisions

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**Polyurethanes**
- MDI
- Polyols
- PO/MTBE
- TPU
- PU Systems

**Performance Products**
- Amines
- Surfactants
- Maleic
- Anhydride
- Upstream Intermediates

**Advanced Materials**
- Systems for Composites
- Adhesives
- Resins

**Textile Effects**
- Dyes
- Chemicals
- Apparel
- Home & Institutional
- Technical Textiles

**Pigments & Additives**
- Titanium Dioxide
- Functional Additives
- Color Pigments
- Timber Treatment
- Water Treatment
Huntsman Advanced Materials
Serving more than 2,000 customers in over 30 countries in three regions

- Americas
- Europe, Middle East, Africa (EMEA)
- Asia Pacific, (APAC), India
Huntsman Advanced Materials
Our focus industries
**Huntsman Advanced Materials**

**Our core business**

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<td>• Solid epoxy resins</td>
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<td>• Epoxy solutions</td>
<td>• Reactive Diluents</td>
<td>• Composites</td>
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Our resins include bisphenol-A, F or A/F chemistries.

Our components give formulators the performance they need.

Our formulations build the products you use every day.

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**Advanced Materials**
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Dynamic Fluid Compression Molding
Summary

• Structural composite parts in less than 1 minute possible (30 sec cure-time)
• Consistent high surface quality and low void content → robust process
• Higher part complexity possible than standard WCM
• Low press force required = lower investment
• Fiber volume content in excess of 60% easily achieved
• Part quality not sensitive to fiber type – even for heavy industrial fabrics
• Simpler parts need no fiber preform

→ Cost-effective structural composite production for high-volume industrial applications

Thank You
For more information

[Links provided]

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