Liquid Compression Molding (LCM) Technology for Mass Production of Continuous Fiber Composite Epoxy Matrix Components

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The car industry implements light weight solutions to comply with CO₂ emission and fuel consumption reduction legislation.
How can we achieve a potential weight reduction of 70% at competitive part cost

CFRP Epoxy Composites

50% material
- 40 - 45% carbon fiber
- 5 - 10% resin

50% processing
- Quicker curing matrix
- Process optimization
- Near-end-contoured preforms
- Automation

Source: Roland Berger
Optimum CFRP performance and cost is complemented with good design.

- HP-RTM
- LCM
- Injection Moulding
- Prepreg
- Towpreg
- Preforming
- SMC
- FiWi

Partnerships Through Value Chain
- Equipment Suppliers
- Part Design and Modeling
- Process Design and Modeling
- Tool Fabrication
- Reinforcements

Materials
- Liquid Resins
- Hot Melts
- Perform Binders
- Mould Release Agents
- Prototyping Systems

Optimum Performance and Cost

Process Capability For OEM Industrialization

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Complimentary Manufacturing Processes:
Resin Transfer Moulding (RTM) and Liquid Compression Moulding (LCM)

Robust process technologies for rapid manufacturing of continuous fiber composites
Compatible for range of simple to complex part geometries

Cycle time < 60s

Molding Temperature, °C
Cycle time, s
In the HP-RTM process, resin is injected into the fabric preform in closed matched metal tooling in a compression press.

Cycle time is driven by number of factors:

- Press and injection equipment
- Part size and complexity
- Resin type and quantity
- Injection flow rate (driven by geometry and preform permeability)
LCM Process Overview

In the LCM process, the resin is applied to the top of the fabric, either outside or inside the open tool cavity. The press then closes and resin is pressed into the laminate, primarily in ‘z’ direction.

Process and Cycle Time Advantages:
- Preforming not required for majority of compatible parts – removing process step
- Faster impregnation of fiber than with RTM injection

Fiber preparation
Liquid resin application
Transfer wet lay-up into mould
Curing
Opening & de-moulding
LCM cycle times of 50 seconds have been demonstrated.
LCM Moulding Tool - Cross Section

Arrows showing direction of impregnation during mold closure

Fabric Stack

Resin Pre-applied to Fiber Stack

Upper Mould Tool

Lower Mould Tool

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Both RTM and LCM require technical expertise and process development.

RTM

Resin Flow/Fiber Impregnation (during Injection)

LCM

Resin Flow/Fiber Impregnation (during Mold Closure)
Liquid Compression Molding (LCM) is cost attractive with increasing complexity of parts.
Considerations to compare for CFRP part cost

Example Part -

Dimensions
Volume (cm³) : 1500 mm x 1200 mm x 3mm
Resin amount (g) : 5.400

<table>
<thead>
<tr>
<th>Process</th>
<th>RTM</th>
<th>High Pressure - RTM</th>
<th>LCM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Injection rate (g/s)</td>
<td>40</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Process temperature (°C)</td>
<td>120</td>
<td>120</td>
<td>140</td>
</tr>
<tr>
<td>Cavity pressure (bar)</td>
<td>15</td>
<td>80</td>
<td>30</td>
</tr>
<tr>
<td>Required injection time (s)</td>
<td>60</td>
<td>24</td>
<td>N.A.</td>
</tr>
<tr>
<td>Tool cycle time (s)</td>
<td>360</td>
<td>93</td>
<td>50</td>
</tr>
<tr>
<td>Injection equipment</td>
<td>3K RTM</td>
<td>3K HP-RTM</td>
<td>3K RTM</td>
</tr>
<tr>
<td>Press (ton)</td>
<td>500</td>
<td>2,500</td>
<td>1,000</td>
</tr>
<tr>
<td>Tooling cost Relative</td>
<td>x1.5</td>
<td>x2</td>
<td>1</td>
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<tr>
<td>Build rate pc/year</td>
<td>20,000</td>
<td>70,000</td>
<td>120,000</td>
</tr>
<tr>
<td>Fixed tooling cost/part Relative</td>
<td>x11</td>
<td>x4</td>
<td>1</td>
</tr>
</tbody>
</table>

Dimensions:
- : 1500 mm x 1200 mm x 3mm
- Volume (cm³) : 5.400
- Resin amount (g) : 2.400
The part size and equipment determine the material processing window.

![Graph showing the relationship between resin shot weight, injection rate, and injection time.](image)

- **Part**: Resin Shot weight (g)
  - 0, 2000, 4000, 6000, 7000

- **Equipment**: Resin Injection rate (g/sec)
  - 60 g/s, 80 g/s, 100 g/s

- **Material**: Injection time (sec)
  - 0, 20, 40, 60, 80, 100, 120

- **Equipment Specifications**:
  - EP TRAC 06170 EK TRAC 06170
    - 33 sec
  - EP TRAC 06150 EK TRAC 06165
    - 45 sec
  - EP TRAC 06150 EK TRAC 06150
    - 95 sec

- **80% of Moulded parts**

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The BMW 7-Series Carbon Core illustrates body-in-white mixed material use

**BMW 7-Series**
Various CFRP parts e.g. roof arc and tunnel reinforcement
BMW
SOP: 2015

**Benefits**
- 40 kg weight reduction vs. steel in the Carbon Core body structure
- Fast curing cycle enabled by Hexion latest resin technology
- Multi material mix – engineered to performance

Source: BMW Group
Applications - Epoxy CFRP LCM & RTM technology for **structural** applications

BMW 7-Series
CFRP roof arc
EP TRAC 06000/
EK TRAC 06130

- Complex part geometry requires HP-RTM process

Benefits
- Designed to the shape of the car body
- Fast curing cycle with HP-RTM
- Outstanding weight / performance ratio

BMW 7-Series
CFRP tunnel reinforcement
EP TRAC 06000/
EK TRAC 06130

- Simple geometry of part is compatible with LCM process

Benefits
- Local reinforcement enhances torsional stiffness
Key Takeaways

Liquid Compression Molding (LCM):
Complimentary moulding process to HP-RTM for molding simple to complex geometry composite parts

Key LCM process benefits:
Fastest process technology for manufacturing continuous fiber composites today – Cycle times less than 90 seconds

Cost competitive:
Robust processing and rapid cycle time for LCM manufacturing makes Epoxy CFRP increasingly competitive as a lightweighting technology