Manufacturing Cost Comparison of RTM, HP-RTM and CRTM for an Automotive Roof for Mass Production

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R&D Composites Project Manager
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Index

1 - Overview of Fagor Arrasate
2 - RTM Variants
3 - Cost Analysis
4 - Conclusions
FAGOR ARRASATE’s Overview
Overview of Fagor Arrasate

Founded in 1957

Headquarters at Arrasate (Spain)
Overview of Fagor Arrasate

Supplying technologies for Automotive Market

- Sheet Metal Stamping Systems.
- Lightweighting with metal:
  - Hot Stamping lines for Steel
- Lightweighting with Composites:
  - SMC, GMT, D-LFT, HP-RTM, CRTM,....
RTM Variants
Composites Overview

RTM Variants

<table>
<thead>
<tr>
<th></th>
<th>RTM</th>
<th>HP-RTM</th>
<th>CRTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impregnation Through</td>
<td>Plain</td>
<td>Plain</td>
<td>Thickness</td>
</tr>
<tr>
<td>Mixing Pressure</td>
<td>Low</td>
<td>Hi</td>
<td>Low</td>
</tr>
<tr>
<td>Impregnation Pressure</td>
<td>Low</td>
<td>Hi</td>
<td>Medium</td>
</tr>
<tr>
<td>Filling + Impregnation Time</td>
<td>Long</td>
<td>Short</td>
<td>Short</td>
</tr>
<tr>
<td>Curing Time</td>
<td>Long</td>
<td>Short</td>
<td>Short</td>
</tr>
</tbody>
</table>
Cost Analysis
Process for Cost Calculation

Case Study
- Type of Part
- Nº of parts/year
- Analyze part characteristics.

Process Simulation
- Timing
- Resin
- Inlets
- Pressure

Cost Calculation
Automotive Roof

- Part: Urban Electric car roof (1500 x 2000)
- Projected Area: 1,72m²
- Thickness in Steel: 3 mm
- CFRP Thickness: 0,7 mm
- Vf = %60
- Production Volume: 90,000 parts/year (7 years / 3 Shifts)
- Same Preform
- Material Cost not considered
Processing Parameters

Resin & Inlets

<table>
<thead>
<tr>
<th>Resin</th>
<th>HP-RTM</th>
<th>CRTM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Araldite LY 564</td>
<td>XB 3585</td>
<td>XB 3585</td>
</tr>
<tr>
<td>Aradur 2954</td>
<td>Aradur 3475</td>
<td>Aradur 3475</td>
</tr>
</tbody>
</table>
### Filling + Impregnating

#### Processing Parameters

<table>
<thead>
<tr>
<th>Process</th>
<th>Injection Pressure (bar)</th>
<th>Filling Time (s)</th>
<th>Clamping Force (ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTM</td>
<td>15</td>
<td>547</td>
<td>194</td>
</tr>
<tr>
<td>HP-RTM</td>
<td>70</td>
<td>117</td>
<td>925</td>
</tr>
<tr>
<td>CRTM</td>
<td>1</td>
<td>42+2</td>
<td>632</td>
</tr>
</tbody>
</table>
Processing Parameters

Filling + Impregnating

RTM
547s

HP-RTM
117s

CRTM
42+2s
Processing Parameters

Pressure Distribution at the end of Filling Stage

RTM

HP-RTM

CRTM
Processing Parameters

Selecting Curing Temperature

$T \rightarrow t_{\text{Curing}} \rightarrow t_{\text{gel}} \rightarrow t_{\text{filling}}$

Curing Degree

Process Window

$t_{\text{curing CRTM}} = 96.5\degree C$

$t_{\text{curing HP-RTM}} = 98\degree C$

$t_{\text{curing RTM}} = 130\degree C$

$t_{\text{filling CRTM}} = 42\text{ s}$

$t_{\text{filling HP-RTM}} = 117\text{ s}$

$t_{\text{filling RTM}} = 547\text{ s}$
## Processing Parameters

### Timing

<table>
<thead>
<tr>
<th>Process</th>
<th>Load preform</th>
<th>Close mold</th>
<th>Inject/cure</th>
<th>Open mold</th>
<th>Extract part</th>
<th>TOTAL (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTM</td>
<td>4</td>
<td>2</td>
<td>1327</td>
<td>2</td>
<td>4</td>
<td>1339</td>
</tr>
<tr>
<td>HP-RTM</td>
<td>4</td>
<td>2</td>
<td>358</td>
<td>2</td>
<td>4</td>
<td>370</td>
</tr>
<tr>
<td>CRTM</td>
<td>4</td>
<td>2</td>
<td>137</td>
<td>2</td>
<td>4</td>
<td>149</td>
</tr>
</tbody>
</table>
Cost Analysis

Cell Cost.

90,000 parts/year
(7 years / 3 Shifts)

RTM
- 7 Presses & Molds & Inj.
- 412 m²

HP-RTM
- 2 Presses & Molds & Inj.
- 127 m²

CRTM
- 1 Press & Mold & Inj.
- 57 m²
## Cost Analysis

### Cell Cost.

<table>
<thead>
<tr>
<th>Process</th>
<th>Press (k€)</th>
<th>Injection system (k€)</th>
<th>Mold (k€)</th>
<th>Robot (k€)</th>
<th>TOTAL (k€)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTM (7)</td>
<td>460 (×7)</td>
<td>170 (×7)</td>
<td>80 (×7)</td>
<td>205</td>
<td>5175</td>
</tr>
<tr>
<td>HP-RTM (2)</td>
<td>700 (×2)</td>
<td>300 (×2)</td>
<td>110 (×2)</td>
<td>150</td>
<td>2370</td>
</tr>
<tr>
<td>CRTM</td>
<td>700</td>
<td>170</td>
<td>97</td>
<td>110</td>
<td>1077</td>
</tr>
</tbody>
</table>
Cost Analysis

Energy Cost

Assumptions:
1. Hydraulic System Waste %30
3. Isolation between mold and ram is perfect.
4. Steel Thickness 500mm (50W/(k*m))
5. Mold is covered with 20mm isolator (0.243W/(k*m))
6. Room temp. 25ºC (5.8W/(k*m))

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RTM</td>
<td>22</td>
<td>4</td>
<td>3.94</td>
<td>0.394</td>
<td>1.17</td>
<td>0.117</td>
</tr>
<tr>
<td>HP-RTM</td>
<td>66</td>
<td>8</td>
<td>2.85</td>
<td>0.285</td>
<td>0.64</td>
<td>0.064</td>
</tr>
<tr>
<td>CRTM</td>
<td>66</td>
<td>8</td>
<td>1.15</td>
<td>0.115</td>
<td>0.32</td>
<td>0.032</td>
</tr>
</tbody>
</table>

Energy cost € 0.1/kWh
**Cost Analysis**

### Roof Cost.

<table>
<thead>
<tr>
<th>Process</th>
<th>Equipment &amp; Tooling (€/part)</th>
<th>Plant (€/part)</th>
<th>Energy (€/part)</th>
<th>TOTAL (€/part)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTM</td>
<td>8.21</td>
<td>0.412</td>
<td>0.406</td>
<td>9.03</td>
</tr>
<tr>
<td>HP-RTM</td>
<td>3.76</td>
<td>0.127</td>
<td>0.349</td>
<td>4.24</td>
</tr>
<tr>
<td>CRTM</td>
<td>1.70</td>
<td>0.057</td>
<td>0.147</td>
<td>1.91</td>
</tr>
</tbody>
</table>

*The plant operating cost is assumed to be € 90/m²/year*
Conclusions
Conclusions

1. CRTM cost is the lowest.
   a) Shorter Injection Time
   b) Higher Molding Temperature
   c) Fast Curing

   SHORT CYCLE TIME

2. CRTM cell should be equipped with a single press, whereas HP-RTM needs 2 and RTM 7.

3. Bigger Plant area for RTM and HP-RTM than for CRTM.

4. Energy consumption in CRTM is 3 times lower than RTM and 2 times lower than HP-RTM.
Conclusions

CRTM is the most suitable manufacturing process for big area and simple geometrical automotive parts, as it is fast and energy efficient, and the initial investment is also lower than the alternatives studied.
Thank you!

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