Long fiber reinforced Thermoplastic LFT-D and Thermosetting D-SMC Processes for lightweight Parts Production – Trends and recent Applications
Outline

+ Motivation for Direct Processes LFT-D (Long Fiber reinforced Thermoplastic Process) and D-SMC (Direct Strand Molding Compound)
+ Technical features LFT-D
+ Recent Applications
+ D-SMC Technology
+ In-Line Compounding Directly Prior to Processing
  + Motivation / Goals
  + Schematic Concept
  + Video: Manufacturing of a VW Front Lid
  + Mechanical Properties (Extract)
+ Summary/Outlook
DIEFFENBACHER Forming Technology - Plastics

LFT-D Technology

- Two-machine technology for **optimum compounding** and **smooth fiber integration**
- Highest **economic efficiency** by avoiding the cost-intensive manufacture of semi-finished products and the related logistic costs
- Individual **adjustment of the compound** to the specific required properties of the component to be produced
- **High quality level** of the components by preserving fibers with a length of >20 mm and more within the component
- Excellent **flow properties**
- In-line processing of **recycled materials**
- More than 40 LFT plants sold
LFT-D: Injection Molding vs. Compression Molding (PP/Glass)

+ Plaque tool (36” x 16”) capable of running injection or compression

+ Measure properties with cut coupons in 0° x 90°

+ Create prototype bolster tool capable of running injection or compression.

+ Evaluate flow, fiber length and processing.

+ Perform side by side tests
Definitions – Injection Molding vs Compression Molding (PP/Glass)

- Short Glass Injection – Traditional injection glass filler: Length < 1mm.

- LFT – Long Glass Injection – Modified screw design allows for longer glass. Final max. length often max 3 – 5 mm. Starting glass length is reduced by runner & sprue shear.

- LFT-D – Direct compounded compression using roving. Final length often 15 – 60 mm glass.
LFT-D: Injection Molding vs. Compression Molding (PP/Glass)

- For better sampling actual load floor part selected
- Tool capable for injection and compression designed
- 4mm thick parts molded in both processes with 40% glass filled PP
- Coupons cut as shown in picture - Tensile, Flex and Impact test runs
- LFT-D Panels showed better properties under Tension, Flex and Impact
# LFT-D: Injection Molding vs. Compression Molding (PP/Glass)

## Average of all samples (Flow / Cross Flow) All coupons @ 40% glass

<table>
<thead>
<tr>
<th>Material</th>
<th>Thickness mm</th>
<th>Tensile Strength MPa</th>
<th>Tensile Modulus GPa</th>
<th>Flex Strength MPa</th>
<th>Flex Modulus GPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>LFT-D Panel</td>
<td>4.01</td>
<td>85.1 (87.5/82.6)</td>
<td>8.0 (8.6/7.4)</td>
<td>143.7 (155.8/137.6)</td>
<td>5.8 (6.0/5.4)</td>
</tr>
<tr>
<td>OEM Approved Injection Panel, 12.5 mm Pellets</td>
<td>3.8</td>
<td>63.5 (81/46)</td>
<td>5.65 (7.2/4.1)</td>
<td>100 (142/59)</td>
<td>6.05 (8.8/3.3)</td>
</tr>
</tbody>
</table>

Note:
* Common tool was flat panel @ 35" x 16" and modified to run injection or compression. Single point injection in center.
* Little variation found with LFT-D charge layout, square stacked or ony ply rectangular.
* Little variation found with test coupon location. Coupons sampled for flow / cross flow under and away from the charge.
* Minimum of 4 coupons each were tested in flow/ X-flow directions and charge/ non-charge areas.
LFT-D Compression Molding – Bolster Development Results

+ Plaque properties showed significant improvement regarding modulus, strength and impact
+ Plaque properties showed significant improvement in 0°x90° uniformity
+ No processing, flow line, knit issues
+ LFT-D fiber length is far superior to injection
  + LFT-D fibers showed length from 20 to 60 mm.
  + Injection Fibers were mostly just fine dust measuring no more than a couple of mm in length
+ DV testing showed improved results compared to injection:
  + Tests where modulus was the criteria were similar
  + Tests where strength and impact were the criteria yielded significant improvement over injection
Frontend Carrier (Evaluation) – Charge Placement & Residual Glass

Sample 1
Glass % 41.25

Sample 2
Glass % 41.16

Sample 3
Glass % 39.72

Sample 4 & 5
Ave. Glass % 40.11

600 mm charge

500 mm charge

500 mm charge
LFT-D Compression Molding (PP/Glass) – Bolster (Evaluation)

Cut-outs of bolster for residual fiber and fiber content investigation
Bolster (Evaluation) – Fiber Length

Bottom section - all flow
Bolster (Evaluation) – Fiber Length

Residual fiber backbone
LFT-D: Injection Molding vs. Compression Molding – Fiber length

Original Sample  Burned Sample  Fiber Samples

Observations:
LFT-D showed fibers as long as 60 mm
Injection Fibers were mostly just fine dust with some measuring a couple of mm in length

Measured 40 % glass
Average Fiber length <2 mm

* Long lines seen are wrinkles in the transparency
X-Ray of LFT-D Plaque
X-Ray of Knit Line with Injection
X-Ray of Longest DLFT Flow
LFT-D/ILC – Applications
Frontend carrier VW Passat B5

First part in LFT-D-ILC mass production (1996)

Source: Menzolit Fibron / Volkswagen AG
LFT-D/GF Technology

Fields of Application

- Material: LFT-D/GF 40 PP
- Parts weight: 3.5 kg
  20 % recyclate
- Cycle time: 40 s
- Line: Hydraulic High-Speed Press, Type DYG 1800/1500
  with active parallel leveling system

Frontend Cross Member
### LFT-D/GF Technology

#### Material Properties

**Frontend Cross Member**

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<th>Property</th>
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<td>Bending strength (DIN 53452)</td>
<td>60</td>
<td>65</td>
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<tr>
<td>Impact strength (DIN 53453)</td>
<td>60</td>
<td>75</td>
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*including 30 % LFT/GMT recylcate*
## LFT-D/GF Technology

### Material Properties

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*including 30 % LFT/GMT recyclate*
Preserving Long Fibers in the Part
X-ray of a Part produced with Dieffenbacher’s LFTD-ILC Technology
Added value from raw materials to part production

Added value: SMC manufacturer
Increased added value: part manufacturer
Added value: part manufacturer

Fibers
Fillers

Quelle: Fraunhofer ICT
Solution Level 2: Processing of D-SMC in Front of the Press

Goals of D-SMC

+ **Manufacturing of D-SMC (Direct-Strand Molding Compound)**
  Dosing and homogenizing of the raw materials, incorporation and impregnation of the glass fibers, compression molding of D-SMC to final parts, in one continuous processing chain.

+ **Constant Quality on Highest Level (Class-A)**
  Just-in-time production of D-SMC generates short control loops by avoiding time consuming maturing stages of conventional SMC as well as the SMC cost intensive logistics.

+ **Reduction of the Cost of Parts**
  by DIRECT acquisition of all raw materials, elimination of external SMC production costs, reduction of production waste (coil trimmings), minimization of void content = less post processing.

+ **Reduction of Cycle Time**
  by a fully automated part production in combination with optimized D-SCM recipes tailored to match the needs of each individual part.

+ **High Flexibility**
  by changing D-SMC recipes on the fly. Individual choice of resins, additives, fillers and fibers enable cost effective D-SMC part production.
Viscosity Profiles

Accelerated thickening
SMC: 2-4 days
D-SMC 2-4 minutes

under consideration of:

+ Fiber impregnation
+ Mechanical properties
+ Tack vs. handling
+ Fiber transport
+ Surface quality
Solution Level 2: Processing of D-SMC in Front of the Press

Schematic
Manufacturing Trial: VW Front Lid in D-SMC
Manufacturing Trial D-SMC
Incorporation of Fibers

- Feeding of rovings (multi or single ended)
- Forced feeding
- Winding tension improves impregnation
- Well established process technology (LFT-D ILC)
Manufacturing Trial D-SMC
Part manufacturing steps

Strand extrusion

Separation

Compression molding

D-SMC part
Fiber Content Distribution: Reference SMC vs. D-SMC

Sample for TGA Ø=25mm
GF-content determination according to VW TL52354

Set value: 30,0 %
Average: 29,7 %
Standard dev.: 1,2 %

500x600mm reference SMC
Fiber Content Distribution: Reference SMC vs. D-SMC

Direct-SMC

Sample for TGA Ø=25mm
GF-content determination according to VW TL52354

Ø 400mm
Direct-SMC

Set value: 31,0 %
Average: 31,4 %
Standard dev.: 1,7 %
Mechanical Properties of D-SMC (Extract)

Bending Stiffness

Bending E-Modulus [MPa]

Quelle: Fraunhofer ICT
Mechanical Properties of D-SMC (Extract)

Bending Strength

Bending Strength [MPa]

Referenz GF 30
GF20 (V56)
GF30 (V55)
GF34 (V52)
GF30 (V58)
GF20 (V60)
GF20 (V61)
GF25 (V63)
GF30 (V65)
GF25 (V66)
GF30 (V67)
GF25 (V68)
GF30 (V69)
GF 30(V72)
GF30 (V71)
GF30 (V74)
GF30 (V75)
GF30 (V77)

Quelle: Fraunhofer ICT

Ernst, Henning, Robbins
Mechanical Properties of D-SMC (Extract)
Surface Quality (Waviness)

Referenz SMC (UP-GF 30)
DuroVision Referenz SMC (UP-GF 28)
SMC in ZSG (UP-GF 28)
HFG + GF in ZSG (UP-GF 34)
FMC (UP-GF 20)

Quelle: Fraunhofer ICT
Comparison of Surface Quality
SMC vs. D-SMC

Class-A SMC (Reference)

D-SMC 1. Generation

D-SMC 3. Generation
Front Lid Exhibited on K-Fair 2007
Summary

+ Feasibility of the D-SMC process could be verified
+ D-SMC provides flexibility in recipes and enables usage of raw materials (glass, fillers, resins, etc.)
+ Accelerating the thickening process is a key issue
+ Only minutes lie between raw material and molded part
+ Mechanical properties are close to those of SMC

Outlook

+ Further optimization of mechanical properties
+ Verification of repeatability in compound- and part production
+ Transformation of the R&D equipment towards a robust shop floor technology