Structural thermoplastic lightweight design for automotive mass production

Compression molding of UD tapes and LFT

S. Baumgärtner¹, T. Huber¹, F. Henning¹,²

¹ Fraunhofer Institute for Chemical Technology (ICT)
² Karlsruhe Institute of Technology (KIT)

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Agenda

- BMBF Lighthouse Project SMiLE
- UD tape processing at Fraunhofer ICT
- Process development
  - Direct LFT
  - Combined process (UD tape and LFT)
- Transfer to large demonstrator part: Composite floor structure
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Systemintegrierter Multi-Material-Leichtbau für die Elektromobilität

Partners

University/ institutes

Fraunhofer IWM
Fraunhofer ICT
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University Stuttgart
ifs
FAST
I AM
TU Dresden

Industrial partners

BASF
Volkswagen
Audi
VOITH
ThyssenKrupp
Dieffenbacher
FWB
Frimo
Aditya Birla

Porsche Engineering

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**SMiLE lightweight car body for e-mobility**

- Holistic hybrid multi-material design
  - Further development of nonferrous metals (aluminum, magnesium)
  - Development of low-temperature cataphoretic painting (KTL) and optimized aluminum alloys
  - Composite floor structure (thermoset and thermoplastic composites)
  - Joining technologies for multi-material design
  - Assembly of demonstrator car body and life cycle assessment

- Range: approx. 200 km
- 13 battery modules with 2.7 kWh each
- > 300 parts per day
In order to develop high-performance lightweight solutions which can be manufactured on an industrial scale, it is essential to concentrate and connect competences in the fields of methods, materials and production.
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Thermoplastic tape processing at Fraunhofer ICT

UD tape

Tailored blank (stacked)

Tailored blank (consolidated)

Fiberforge 4.0 (automated tapelaying)

Fibercon (radiation-induced vacuum consolidation)
The efficient route to tailored blanks made of UD tapes

Fiberforge 4.0 available at ICT, Pfinztal
The efficient route to tailored blanks made of UD tapes

Fibercon (a.k.a. radiation-induced vacuum consolidation) available at ICT, Pfinztal
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Process development:
Local advanced tailored long fiber thermoplastics (LFT)

- Benefit of LFT compression molding:
  - Economic process for large parts with low cycle times

- Benefit of advanced LFT compression molding:
  - Use of engineering thermoplastics enables new applications (higher loads, chemical resistance, higher temperature conditions)

- Benefit of advanced tailored LFT:
  - Continuous-fiber reinforcements in main load path enable structural applications

Side view

Cross-section

UD tape

LFT
Process development:
Local advanced tailored long fiber thermoplastics (LFT)

- **Goal**
  - Further reduction of part weight
  - Reduction of wall thickness through use of continuous-fiber-reinforced tapes
  - Only local use of LFT to reinforce the structure, and to avoid buckling of tape laminate and add functions (inserts, ...)

  → Development of new process **local advanced tailored LFT**
Process concept

- Displaceable cavity
- Rib
- UD tape
- LFT

$F_p$: press force
$F_V$: press force of displaceable cavity
Process concept (animation)
Process concept (test part)

- Mold temp.: 80 °C
- D-LFT: PA6 (BASF-B3K) + 40 wt.-% e-glass fiber
- UD tapes: BASF Ultratape B3WC12 (PA6 with 60 wt.-% carbon fibers)
  - 13 layers with total thickness of 2.1 mm
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D-LFT Process

Polymer + additives

Inline compounder

Mixing extruder with die

LFT plastificate (open transfer)

Compression molding
D-LFT form filling parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Width of initial charge</td>
<td>175 mm</td>
</tr>
<tr>
<td>Length of initial charge</td>
<td>170 mm</td>
</tr>
<tr>
<td>Height of initial charge (nozzle setup)</td>
<td>12 mm</td>
</tr>
<tr>
<td>Press force / Cavity pressure</td>
<td>3000 kN / 200 bar</td>
</tr>
<tr>
<td>Tool temperature</td>
<td>80 °C</td>
</tr>
</tbody>
</table>
D-LFT form filling
D-LFT form filling
D-LFT form filling
D-LFT form filling
D-LFT form filling
D-LFT form filling
D-LFT form filling
D-LFT form filling
Combined process (UD tape and LFT)

- Rib filling influencing parameters
  - LFT temperature (not varied)
  - Position, size and direction of initial charge
  - Closing profile
  - Mold temperature
  - Press force
  - Tape temperature
    - 80 °C
    - 130 °C
    - 275 °C (before transfer)
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Tape temperature above crystallization

- Computer tomography

- SEM

Melted UD tape gets infiltrated/ misaligned if LFT flows against flank
Tape temperature below melting temperature

- Computer tomography

Solid UD tape stays in position. Interface strength?
Shear edge test

- Preparation

- Testing

Testing method developed by: KIT Institut für Angewandte Materialien - Werkstoffkunde (IAM-WK)

Shear edge test

- Preparation

- Results

  - Interface strength at 80 °C below 10 MPa
  - Interface strength at higher temperatures:

  [90/0] 2mm 130°C

  [90/0] 2mm 275°C

Similar interface strength if interface temperature is at least 130 °C
Transfer into more complex ribs

Results were used for calibration of the moldflow simulation
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AP3 Demonstrator: Composite floor structure

One-shot hybrid thermoplastic composite part

Aluminum profiles

LFT-D including metallic inserts

UD tape

~1300 mm

~1300 mm
Structural and crash simulation (BASF Ultrasim)

Responsible project partner: Sebastian Ebli, BASF
Process simulation: Draping simulation (Abaqus-based)

Sequential forming of UD tape

Responsible project partner: Dominik Dörr, KIT FAST
Process simulation: Draping simulation (Abaqus-based)

- Optimization of net shape tapelaying

Responsible project partner: Dominik Dörr, KIT FAST
Process simulation: Form filling (moldflow)

Responsible project partner: Martin Hohberg, KIT FAST

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Summary

- Process was developed and feasibility could be demonstrated
- Formfilling was optimized by variation of process parameters

- Hollistic development of demonstrator part

- To be continued…
Thank you for your attention!

Contact details

M.Eng Sebastian Baumgärtner
Team Leader Thermoplastic Processing
SMiLE WP3 Leader – Thermoplastic Composites
Fraunhofer-Institut für Chemische Technologie ICT
Joseph-von-Fraunhofer-Str. 7, 76327 Pfinztal, Germany
Tel.: +49 721 4640-830
Fax: +49 721 4640-800-830
Sebastian.Baumgaertner@ict.fraunhofer.de
www.ict.fraunhofer.de