Composite battery housing based on (CF-)SMC/Prepreg technology

SPE ACCE 2021
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Agenda

- Introduction HRC Group & ACTC
- Composite battery housing based on (CF-)SMC/Prepreg technology
  - Project Motivation
  - Process Chain and Materials
  - Engineering and Simulation
- Summary & Outlook
HRC Group: Some facts

Founded in year **2014**...

Over **900** employees in **4** different countries...

**1/3** R&D staff of total team...

Over **70** international and domestic clients...

**4** business units with different specialization and focus...

**NO. 1** market share for carbon fiber parts supply in China...
HRC Group: Some facts

After 7 years of rapid development, HRC has grown into a company group covering different segments for composite parts developing and manufacturing, facing the growing needs from various key target industries.

- **Composite design, engineering & material characterization**
  - Automotive
  - Aerospace and Railway

- **R&D, process engineering & trial production**

- **Mass Production Centers**
企业化管理运作的开放研发平台
Open R&D Platform

德国弗劳恩霍夫化学技术研究院
Fraunhofer ICT

中国恒瑞有限公司
Hengrui Corporation

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No. 59, Huangpujiang Road, Changshu National New & High-tech Industrial Zone

规模：8000平方米
8000㎡

投资总额：2000万欧元
20 million Euro

完成时间：2019年底前
By Q4, 2019
Main Technologies

**Thermoset**
- Compression molding
- SMC & C-SMC

**Thermoplastic**
- Injection molding
- Compression molding

**Hybrid Solutions (Metal-Composite)**
- Resin Transfer Molding (HP-RTM)
- Wet Compression Molding (WCM)
- Prepreg Compression Molding (PCM)
- Pultrusion / Pulwinding
- Filament Winding (FW)

- Automated Tape Laying
- UD / Organo Sheet Thermoforming
- Back Injection Molding
- Pultrusion

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Full solution R&D platform
Composite battery housing based on (CF-)SMC/Prepreg technology
Project Motivation – EV Market Trends

- Development of sustainable & innovative lightweight traction battery system
- Growing market: announcements of German car manufacturers
  - BMW: 12 new battery electric models by the year 2025
  - Mercedes: All model series will be electrified until 2022
  - VW: 50 new battery electric vehicles and 30 new plug-in models until 2025
  - Porsche: In 2030, 50 % of all Porsche vehicles sold will be electrified
- Trend towards higher battery capacities

Mercedes EQC: 80 kWh*
Audi Q4 e-tron: 77 kWh*
Tesla Model S: 100 kWh
Mercedes EQS: 108 kWh*

*Net capacity

Source: Mercedes
Source: Tesla
Source: Audi
Source: Mercedes
Project Motivation – Safety Requirements

Safety aspects of EV car concepts

Battery as part of the safety concept
Project Motivation

- Technical challenges of battery systems and housing solutions...
  - **Battery Safety**: in the case of crash and abuse including impact, fire protection,... (e.g. GB38031-2020 (China), UNECE R100 (Europe))
  - **Thermal Management**: fast-charging capability, sealing concept
  - **EMI Shielding**: need for protection against electromagnetic interference with other vehicle components and environment
  - **Lightweight**: high-performance lightweight structures allow a high weight-specific energy density
    - Tesla Model 3 (Long Range RWD): 75 kWh, 600 km (WLTP), **478 kg**
    - VW ID.3 Pro Performance: 58 kWh, 426 km (WLTP), **495 kg**
    - BMW iX3: 80 kWh, 460 km (WLTP), **518 kg** (cover: SMC)
    - Mercedes EQC: 80 kWh, 462 km (NEFZ), **650 kg**

- First step: development of lightweight battery housing as one part of an innovative battery concept (outlook)
SMC Battery Housing for BEV/HEV/PHEV

- Entire electrical energy storage system
  - Including battery modules, BMS and an integrated PDU (Power Distribution unit)
  - Battery modules are based on existing Samsung SDI Modules
- Designed to accommodate 2 different battery types
  - Either 4 battery modules e.g. used in the BMW i8 (left)
  - Or 2 battery modules e.g. used in the BMW i3 (right)
SMC Battery Housing for BEV/HEV/PHEV

- Housing closure head & connectors
- Power distribution unit (PDU) / battery management system (BMS)
- Battery modules
- Base plate & cooling
SMC Battery Housing for BEV/HEV/PHEV

- FRP composites housing with integrated functionalities
  - Metal inserts for assembling housing & baseplate
  - Lightweight potential
  - 3D shape
  - High volume production process
- CF-SMC / GF-SMC with local reinforcements
Sheet Molding Compound (SMC)

- SMC is a flat semi-finished product typically made of cross-linkable resins (UP, VE, EP, PU, hybrid), chopped reinforcement fibers (GF, CF, NF,…), mineral fillers and additives
- Quasi-isotropic properties due to randomly distributed fibers
- The production of components made of SMC can be divided into three/five temporally and spatially separable processes:
Materials

Material combinations

- GF SMC
- GF SMC + CF UD Prepreg
- CF SMC
- CF SMC + CF UD Prepreg
- Material partners:
Manufacturing & Preforming of UD CF Prepregs

- ZOLTEK PX35 Stitch-Bonded Uni-Directional Carbon Fabrics
  - Produced from our ZOLTEK PX35 50K Continuous Tow Carbon Fiber
  - Fabric weight 300 g/m² / Fiber content: 60 wt.-%

- AOC Daron Non-Flow hybrid resin
  - Adjusted chemistry based on resin system used for SMC
  - Enabling robust preform inlays for co-molding process
# UD prepreg and preform part

## Cutting and stacking of the preforms

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting</td>
<td>Automatic process on ZÜND cutting table</td>
</tr>
<tr>
<td>Stacking</td>
<td>Manual process</td>
</tr>
</tbody>
</table>

## PCM preforming process

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Curing time</td>
<td>12 min</td>
</tr>
<tr>
<td>Temperature</td>
<td>85 °C Upper tool</td>
</tr>
<tr>
<td></td>
<td>80 °C Lower tool</td>
</tr>
<tr>
<td>Inlay thickness</td>
<td>1 mm – 3 layers</td>
</tr>
<tr>
<td>Preform part weight</td>
<td>0.5 kg</td>
</tr>
</tbody>
</table>

- UD prepreg cutting and stacking
- UD preform inlay – PCM process
Specifications and benefits

- Integration of continuous fibers into the SMC material
- Advantage of continuous fibers → high strength and stiffness
- Usage of continuous fibers only where it is necessary and beneficial
- Advantage of SMC → complex part geometries, short cycle times, integration of inserts
### Co-Molding Process SMC + Prepreg

**SMC co-molding process**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure</td>
<td>4,800 kN</td>
</tr>
<tr>
<td>Molding project area</td>
<td>0.55 m²</td>
</tr>
<tr>
<td>Curing time</td>
<td>180 s</td>
</tr>
<tr>
<td>Mold Coverage</td>
<td>70-80 %</td>
</tr>
<tr>
<td>Temperature</td>
<td>150 °C Upper tool</td>
</tr>
<tr>
<td></td>
<td>145 °C Lower tool</td>
</tr>
</tbody>
</table>

**SMC material**

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GF-SMC material</td>
<td>AOC GF-SMC</td>
</tr>
<tr>
<td></td>
<td>Fiber content 40 wt.-%</td>
</tr>
<tr>
<td></td>
<td>Hybrid resin</td>
</tr>
<tr>
<td>CF-SMC material</td>
<td>Mitsubishi CF-SMC</td>
</tr>
<tr>
<td></td>
<td>Fiber content 53 wt.-%</td>
</tr>
<tr>
<td></td>
<td>Epoxy acrylate resin</td>
</tr>
</tbody>
</table>

GF-SMC with UD prepreg co-molding

10 Metal knurled screw inserts
## Materials Used

<table>
<thead>
<tr>
<th>Materials Used</th>
<th>Estimated Part Mass*</th>
<th>Mass Change</th>
<th>Estimated Stiffness*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(including inserts for composites)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stamped Aluminum</td>
<td>6.50 kg</td>
<td>0 (baseline)</td>
<td>70 GPa</td>
</tr>
<tr>
<td>GF-SMC + UD/CF-prepreg</td>
<td>4.90 kg</td>
<td>25 ↓ %</td>
<td>GF-SMC: 11.5 GPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prepreg: 120 GPa</td>
</tr>
<tr>
<td>CF-SMC + UD/CF-prepreg</td>
<td>3.90 kg</td>
<td>40% ↓</td>
<td>CF-SMC: 42 GPa</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prepreg: 120 GPa</td>
</tr>
</tbody>
</table>

*Values estimated from CAE results for comparably performing and similar-looking designs.
C-SMC Battery Box Co-Molding
Simulation approach for SMC process simulation

- SMC Battery Cover has a complex initial charge stacking to ensure complete filling
  - 6 rectangular sheets are assembled to a 2D initial charge
  - Assembled initial charge is manually preformed

- Molding simulation follows a two-step procedure to account for the complex initial charge stacking:
  - Preforming simulation
  - Mold filling simulation

Original preformed SMC initial charge stack
Preforming simulation

Advanced preforming simulation

- Usage of proprietary material and friction models from Simutence to predict preforming
- Preforming simulation result of the initial charge assembly shows good match with real configuration
- Preformed initial charge is transferred to mold filling simulation
Mold filling simulation

**Advanced SMC modelling**
- Usage of proprietary material modeling approaches
  - Anisotropic viscosity
  - Lubrication layer between SMC charge and tool
- Material card obtained from SMC-specific material characterization approaches

**Process simulation outcome**
- Complete mold filling of the cavity could be demonstrated
- Initial configuration can be used for robustness analysis
- Results (e.g., fiber orientation distribution) can be transferred to structural simulation

Mold filling simulation with transfer initial charge from preforming simulation
Summary & Outlook
Summary & Outlook

- HRC is participating in a German research project “ProfilRegion”
- Development of a sustainable lightweight traction battery system
  - Impact Protection (protection of battery cells against physical damage)
  - Sustainability (Life Cycle Analysis; validation of recycling materials)
  - Connection to Vehicle (integrated plugs for electrical, cooling, monitoring; quick change system)
  - Cooling (integrated in structure; optimized by CFD; suitable for fast charging)
  - Sealing (less sealing effort by less components; components with integrated 3D sealing function)
  - Electro Magnetic Shielding
  - Flame protection
Summary & Outlook

System specification:
- Voltage: 800 V
- Capacity: 96 kWh
- Load-bearing packaging in the underbody
- Use of pouch cells

Target application:
- Commercial vehicles, e.g. vans, flatbed trucks, etc.
Goal: Use of Innovative Lightweight Materials in the Appropriate Components - System Level

System frame:
- Aluminum extrusions

System floor:
- Sandwich construction: continuous fiber reinforced deck layers with foam core
- Manufactured using the Direct Sandwich Composite Molding process (D-SCM)
- Integrated cooling lines in the floor

System cover:
- Sheet Molding Compound
- Flame retardant
- Local continuous fiber reinforcements

Module cover:
- Manufactured using the fiber injection molding process
- Locally adaptable material properties for targeted stiffness increases
- Integration EMI protection
Thanks to our partners