Thermoplastische Composites -
Vom Verbundwerkstoff zur Innovation

23. Technologie- und InnovationsFORUM
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Ulf Breuer
Outline

TPC - But why?

Perspectives

New Developments

Conclusions
Beyond 2020: Potential & Challenges

TODAY

**Aero**
- Higher Payload
- Lower DOC (fuel, maint.)

**Auto**
- Weight Reduction
- Range Extension

**Wind**
- Glass Fibre Composites
- Manual Manufacturing

**Machines**
- Niche Applications
- High Performance

>2020

- “Vision 2020” und “Flightpath 2050”
- Reduction of NOx und CO2

- New OEMs (China, Russ.)
- Increasing Prdn. Rate
- Lower Manuf. Cost

- New Emission Standards
- Lower Manuf. Cost, Affordable Lightweight
- High Volume Production
- Sustainability

- Highly Efficient Large Rotorblades
- Low Maintenance
- Automated Manufacturing
- Low Cost Large Volumes
- Higher Velocities
- Dynamic Requirements
- Optimized Tribology

Sep 2017  Ulf Breuer
Most large, complex shaped and highly loaded structures are manufactured with **thermoset material systems**.
Fibre Production

- Fibre-matrix adhesion optimized for thermoset

Impregnation (thermoset)

- Expensive prepregs, limited shop life

Automated Tapelaying

- Production waste

Curing (Autoclave)

- Long cycle time, expensive consumables, non-value-steps

Milling and QA

- Re-work (porosity, delamination, insufficient cure..), bad tolerances

Assembly and Painting

- Shimming necessary, welding not possible

Processes with thermoset material systems have challenges, leading to high cost.
Thermoplastic Composites (TPC) must be more economic than thermoset composites!
Thermosets are hardening (curing) by chemical interlacing. These interlaces avoid free movement of the polymer chains.

Thermoplastics are meltable — softening and hardening are reversible as a function of temperature.
Thermoplastic Composites
TPC….but why?

Meltability
- infinite storage / work life
- out of autoclave technologies
- rapid consolidation & short cycle times
- primary moulding (melt flow)
- high fly to buy
- weldability
- easy repair
- simplified recycling

Performance
- e.g. compression strength (h/w* - 2%; EP: -20%)
- in-plane shear strength (+40% vs EP)

*70°C, 85% rel humidity
State of the Art Thermoforming (Stampforming)

Semi-finished material manufacturing

Components

Thermoforming

Laminates fully impregnated and consolidated

State of the art stamp forming technology enables high quality TPC parts in ~2 min cycle time!
Innovative Materials
A350 Thermoplastic Composite Clips

- very short cycle time technology
- ~10,000 clips per aircraft
- increasing production rate from 80,000 clips per month (2016) to 130,000 clips per month (2017)

Successful joint project in cooperation with Premium Aerotec and Airbus!
Multiaxial TPC Semi Finished Material “Rapid Technologies”

Rapid tape laying technology with smaller tape width enables **high fly to buy ratio and cost savings!**

- **Dimensions:** 3.98m x 2.65 m
- **325 mm**
- **50 mm application unit**
- **25 mm application unit**
- **Red = waste**
  - 30.3%
  - 16.3%
Advanced rapid tape laying technology will enable very high deposition rates of > 100kg/h!
The **lightweight** potential improves with **fibre length**. Highly loaded structures have perfectly orientated continuous fibres!
Master Nature
Composites Light Weight Potential

- smart combination of materials & processes
- very short cycle times
- high part complexity
- excellent mechanical performance

Injection molding/compression molding

“SpriForm”

thermoforming of organo sheets

stiffness, strength, energy absorption

outer belt: continuous fibres

ribs: discontinuous fibres

Thermoforming and moulding – a successful technology development!

BMBF-Project in cooperation with Audi, Bond Laminates, HBW Gubesch, Krauss Maffei, Lanxess
Composite Manufacturing Technologies
Advanced Joining

Large and complex structures require efficient joining technologies!
Thermoplastic Composites

Welding

- Induction causes alternating magnetic field
- Dominant heating mechanism: Eddy currents induced in electrically conductive materials; additional heating mechanisms: Hysteresis, dielectric and contact resistance heating
- Welding susceptor applicable for glass fibre reinforced laminates
- Intrinsic heating ability of carbon fibre reinforced composites (and metals)

**Inductive welding** of carbon fibre reinforced thermoplastic composites is possible without any additional material!
### Recycling

Recycling of CFRP is key in order to improve LCA and CO₂ footprint!

<table>
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<th>resource</th>
<th>unit</th>
<th>carbon fibre</th>
<th>epoxy resin</th>
<th>aluminium sheet</th>
<th>steel sheet</th>
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<td>energy consumption for production</td>
<td>[MJ/kg]</td>
<td>200…400</td>
<td>130</td>
<td>150</td>
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<tr>
<td>CO₂-equivalent</td>
<td>[kg CO₂/kg material]</td>
<td>10…20</td>
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<tr>
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<td>[€/kg]</td>
<td>20…100</td>
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Recycling
“Endless” rCF-Rovings….and “High Perfo”

roving made out of recycled carbon fibres

thermoplastic fibres

New recycling technologies will enable “endless fibre” properties!
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New Developments: Multifunctionality by Metal Fibres

$v = 4.4 \text{ m/s, } m = 19.965 \text{ kg, } E = 193 \text{ J}$

**Significant damage tolerance improvements by metal fibres!**
New Developments: Morphing Structures with Shape Memory Alloy (SMA) Fibres

Composite laminate with integrated SMA wires (0.1…1 mm)

Hybrid laminates with integrated SMA wires can be manufactured.

Actuation is possible by electrical current and ohmic resistance at 60…70°C.
New Developments: Morphing Structures

Morphing Composite Structures enable…

- actuation on demand
- low weight
- very small size
- flat surface when stowed
Conclusions

- Thermoplastic composites are **already demonstrating cost & weight benefits** for various airframe applications.

- **New technologies** such as rapid tape laying, combined forming and melt flow manufacturing as well as induction welding will enable **efficient processing** also for **large and very complex shaped parts**.

- New **recycling** technologies will lead to mechanical properties close or equal to **endless fibre mechanical performance**.

- In the future, **hybrid composite structures** with metal and carbon fibres will reduce cost and add product value by **multifunctionality**.