New possibilities for mass production of sandwich structures

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ROHACELL® industry breakdown

*Lifestyle: sports equipment, medical tables, electronics, radomes
ROHACELL® locations
Positioned to serve a global market

Darmstadt (Germany)
Production: Casting·Foaming·Cutting·Shaping
Sandwich Technology Center

Mobile, Alabama (USA)
Production: Foaming·Cutting·Shaping
Sandwich Technology Center

Shanghai (China)
Production: Cutting facility - in progress
Sandwich Technology Center
An emerging option to meet the innovation demands:

Structural composite sandwich construction.
Why use sandwich construction?

Why not?
Get the best performance out of a sandwich part by using ROHACELL®

**Design**
- Homogenous and isotropic material behavior
- Design freedom: complex, integral, light, strong

**Processing**
- Quick curing (fast, one shot co-curing)
- Easy lay-up, no potting
- Good skin consolidation / tight skin / avoid re-work
- Stable process with high yield, no core stabilization cycle
- Precise core fit, no adjustments needed

**Logistics**
- Fewer parts, no secondary bonding
- Outsourced shaping / no waste
- Quality, ready-to-use parts / low inventory

**In Service Performance**
- No freeze damage or skin debonding
- Excellent fatigue
- Low finished part weight
- Easy to repair
- No water ingress
Example for a sandwich solution: Hatchback - 4 different options

<table>
<thead>
<tr>
<th></th>
<th>steel / glass double shell</th>
<th>al / glass double shell</th>
<th>CFRP / PMMA double shell</th>
<th>CFRP / PMMA sandwich</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheet thickness</td>
<td>0,7 mm</td>
<td>tbd</td>
<td>tbd</td>
<td>tbd</td>
</tr>
<tr>
<td>Thickness: glazing</td>
<td>4</td>
<td>-</td>
<td>tbd</td>
<td>tbd</td>
</tr>
<tr>
<td>Thickness: foam core</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Weight</td>
<td>21,2 kg</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Dominating load cases

- Torsion
- Bending 1
- Bending 2
- Pulling corners
- Local deformation
- Modal analysis
Load case: “Torsion”

Dimensioning load case:
- Boundary conditions on hinges and lock
- Force couple of F=100 N on edges of lid
- Maximum deflection from all load cases
- Glazing has a major effect on torsional stiffness

Four material options:

<table>
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<th>CFRP / PMMA double shell</th>
<th>CFRP / PMMA sandwich</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sheet thickness</strong></td>
<td>0,7 mm 4</td>
<td>1,3 mm 4</td>
<td>2 mm 5</td>
<td>0,75 mm 5</td>
</tr>
<tr>
<td><strong>Thickness: glazing</strong></td>
<td>4</td>
<td>4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Thickness: foam core</strong></td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Weight in kg (reduction in %)</strong></td>
<td>21,2 kg 11,9 kg 9,3 kg</td>
<td>16,9 kg (-20%) 7,6 kg (-36%) 9,3 kg</td>
<td>11,8 kg (-44%) 6,4 kg (-46%) 5,4 kg (-32%)</td>
<td>10,2 kg (-52%) 4,8 kg (-60%) 5,4 kg (-32%)</td>
</tr>
<tr>
<td><strong>Weight without glazing</strong></td>
<td>5,9 mm</td>
<td>6,2 mm</td>
<td>6,3 mm</td>
<td>6,3 mm</td>
</tr>
<tr>
<td><strong>Load case “Torsion”</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Maximum deformation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Demonstrator and evaluation part: Nose Landing Gear (NLG) Door

Foam/Infusion
This foam sandwich part was originally constructed as a 71/200 WF core in infusion technique for Do728. Now it is optimized for 71 HERO/dry fabrics and stay in infusion technique.

Honeycomb/Prepreg
Baseline for the comparison is the NLG door similar to the A320 design and process using Nomex honeycomb (64 kg/m³, 4.8 mm) and prepreg (Fibredux 913C-926-40%).

Foam/Prepreg
Additional we compare the foam with Autoclave (Prepreg) process in case a honeycomb is changed by foam but the process stay the same.
Sandwich construction leads to the lightest available final parts.
It can also offer significant cost reduction in mass production.
Requirements from OEMs: “Competitive costs for composites”

Production process has the biggest potential to decrease costs!

Reduce production costs

Increase production volume

Choose the right core
Requirements for sandwich cores

**Composite** sandwich construction is an emerging option to meet innovation demands coming from many industries, from automotive up to sport industry.

It leads to the **lightest** available **final parts** and can also offer significant **cost reduction** in mass production.

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Core properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lightweight design</td>
<td>High mechanical strength at low density</td>
</tr>
<tr>
<td>High surface quality</td>
<td>Fine and closed cell foam</td>
</tr>
<tr>
<td>Fast cycle times</td>
<td>High temperature and high compression resistance</td>
</tr>
<tr>
<td>Processability</td>
<td>Easy to shape</td>
</tr>
</tbody>
</table>

**ROHACELL®** is a PMI-based structural foam core that meets all requirements for fast curing processes.
Mass production with ROHACELL® products

→ HERO

→ New thermo-shaping technique

→ Innovative “In Mold Foaming”
The ROHACELL® HERO development challenge:
Improve a proven, high performing foam sandwich core product for use in Class A and B parts.

**Add:** High damage tolerance & visibility

**With:** Greatly improved elongation at break

**Keep:** All existing advantages

**Result:** Reduced finished part costs
HERO outperforms Honeycomb

4 - Superior
3 - Excellent
2 - Very good
1 - Good
0 - Unacceptable

- Damage visibility
- Water ingress
- Part cost
- Surface quality
- Part weight
- Design freedom
The time advantage: Where are the main differences?

Comparison of time by process step

- Honeycomb/Prepreg
- Foam/Prepreg
- Foam/Infusion

The time advantage: Where are the main differences?

- Prepreg instead of infusion
- 2 shot curing
- Core handling
- Core handling

Where are the main differences?
Cost advantage results:
Save 21 – 25 % by using foam

Cost comparison NLG door

<table>
<thead>
<tr>
<th>Material cost</th>
<th>Labor + Machine cost</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Honeycomb/Prepreg design</td>
<td>Foam/Prepreg design</td>
<td>Foam/Infusion design</td>
</tr>
<tr>
<td>100%</td>
<td>139%</td>
<td>142%</td>
</tr>
<tr>
<td>100%</td>
<td>59%</td>
<td>53%</td>
</tr>
<tr>
<td>100%</td>
<td>79%</td>
<td>75%</td>
</tr>
</tbody>
</table>

Labor 55€/h
Machine + Labor 85 €/h
Introducing: ROHACELL® HERO
New design opportunities

Pylon Aft Secondary Structure
Access Panels
• carbon epoxy or thermoplastic skins

Nose Landing Gear Doors
• carbon fiber epoxy skins

Main Landing Gear Doors

Floor panels
• carbon epoxy skin

Empennage Leading and Trailing Edges
VTP tip
VTP panels
Dorsal fin

Spoilers / Ailerons

Flap Track Fairings
• carbon/glass epoxy skins

Wing Leading and Trailing Edge Panels
Access Panels

Fuselage Belly Fairing
• carbon/glass epoxy skins
New thermo-shaping technique

Thermo-shaping ROHACELL® has been state of the art technology for more than 30 years.

However, classic thermo-shaping usually requires lengthy heating cycles for ovens and heating plates.

With the new thermo-shaping technique, the process is now shortened to ~2 min – making ROHACELL® ideal for mass production.

Shorten the cycle time for shaping
New thermo-shaping technique

• Fully automated process
• Standard thermo-forming machine (e.g., Geiss T9)
• Cycle time up to 2 minutes
• Sheets up to 60 mm thick can be shaped

• Heating occurs at the top and bottom using IR „Flash“ spots
• Intensity of IR heating elements can be individually controlled
• Both heating areas move in and out separately to a holding position to allow molds to move into the required position
Shaping principles

- upper heater
- blank holder
- RC sheet
- hot air
- vacuum active
- lower heater
- mold
Shaping with a double-sided mold

- Shape highly complex parts
- Vary thickness in a single part using material compression
- Sandwich manufacturing with thermoplastic face sheets can be shaped in one step
- No cell crushing → local compaction leads to higher mechanical properties since density is increased
- Die-cutting in the mold eliminates additional milling steps
New design possibilities using ROHACELL® Triple F core

Standard production of ROHACELL® foam sheets

The newest product technology from Evonik is ROHACELL® Triple F core

New approach for production of cores

- Pellets
- Filling the mold
- Foaming
- Cooling
- Demolding
- Ready-to-use cores
Innovative “In-Mold Foaming”

The newest product technology from Evonik is ROHACELL® Triple F.

A PMI chemistry-based particle foam that can be foamed in a mold to create geometrically complex parts – with very tight tolerances.

With In-Mold Foaming, inserts can be easily integrated into the part during the core foaming process.

Tight tolerances, integrated inserts
A strong, but extremely lightweight core.

When using carbon fibers, you do not want more weight in the core than is necessary.

Depending on the part / process requirements, cores can be produced in a customized density range between 70 – 200kg/m³ or more.
Thermal behavior of ROHACELL® Triple F

Use the full temperature performance of the resin.

The temperature resistance of the part depends on the glass transition temperature ($T_g$) of the resin.

To reach that $T_g$ one has to cure at a temperature above the $T_g$ of the resin.

The $T_g$ of ROHACELL® Triple F (~200°C) is significantly higher than the $T_g$ of all commonly used resins.
Process benefits with ROHACELL® Triple F

Speed up the curing process.

High temperatures and injection pressure shorten the curing cycle time for RTM or wet pressing.

ROHACELL® Triple F processing conditions

Temperature: up to 140°C and
Pressure: up to 6 MPa

Source: data sheet HexFlow® RTM6 from Hexcel
Process benefits with ROHACELL® Triple F

Improvement of process with stable material.

Reduce manufacturing costs related to:

- time
- materials
- processing

No outgassing due residual chemical reactions that can restrict adhesion of layers.

The cores have a high fault tolerance due the particle structure. Tight tolerances are possible.
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Conclusion

- Lightweight design is required by the OEM
- The lightest design principle is composite sandwich
- The main hurdle for composites is cost
- To reduce processing costs, new curing processes are available and will be developed further
- For all new curing methods ROHACELL® could be used as sandwich core
- New mass production processes with ROHACELL® products are available:
  - HERO
  - New thermo-shaping technique
  - Innovative “In Mold Foaming”