Andreas Kiefer

CHALLENGES OF HYBRID JOINING TECHNOLOGY FOR MULTI-MATERIAL DESIGN
AGENDA

- General Demands
  - CO² Legislation
  - Market Demand Safety & Comfort
- Car Body
  - Lightweight Car Body & Multi Material
  - Joining Technologies & Hybrid Joining
- Joining Technology Basics
  - Bonding
  - Flow Drilling
  - Self-Pierce Riveting
  - Spot Welding
- Hybrid Joining
  - Examples
  - Reason & Challenges
GENERAL DEMANDS - OVERVIEW

Lightweight Design (Multi Material Mix)

New Joining Technology

CO$_2$ Legislation

Safety

Demographic Change

Urbanization

Comfort

Megacities

Modularity (Global Platform)

Alternative Powertrain (Hybrid, Electric)
GENERAL DEMANDS - CO² LEGISLATION

- Reduce car weight
  (≈ 10% less weight = ≈ 5% less CO²) Source: SAE CAFE 2025
- Improve efficiency
GENERAL DEMANDS - SAFETY & COMFORT

- Drive Assist Systems to reduce risk of collisions (+weight!)
- More comfort & convenience & electronics (+ weight!)
- Crash improved car body structures (if something happens you feel safe)

Source: Cordis Europe 2014
CAR BODY - LIGHTWEIGHT INDEX

- Lighter cars but stiffer and more rigid car bodies

Source: SCA (top), Volkswagen (bottom)
CAR BODY - LIGHTWEIGHT INDEX

$$L = \frac{m_K}{c_T \cdot A}$$

- L: Lightweight index
- mK: Mass of body-in-white (excluding doors and hoods)
- cT: Static torsional rigidity
- A: Vehicle footprint

Lighter cars but stiffer and more rigid car bodies
CAR BODY - LIGHTWEIGHT INDEX

Example Car Body Fender Based on Appr. 60,000 pcs./p.a.

- Weight
- Cost

Steel: -20% HSS: 15% Plastic: -20% Alu: -40% Carbon: -50%

Lighter cars but stiffer and more rigid car bodies
CAR BODY – MULTI-MATERIAL MIX

- Multi-Material mix in car body
  - To reduce weight plus improve stiffness

Source: Audi, Audi TT Body Structure
CAR BODY – MULTI-MATERIAL MIX

- Multi-Material mix in car body
  - To reduce weight plus improve stiffness
CAR BODY - JOINING TECHNOLOGIES

Mechanical Joining

Combination of Joining Technologies

Substance-to-substance Joining, e.g. Bonding

Thermal / Mechanical + Bonding = Hybrid Joining

Source: DLR
CAR BODY - JOINING TECHNOLOGIES

Thermal / Mechanical + Bonding = Hybrid Joining
CAR BODY - HYBRID JOINING

- Self Pierce Rivet
- Standard Rivet
- Clinch
- Spot Welding

Thermal / Mechanical + Bonding = Hybrid Joining

Source: DLR
JOINING TECHNOLOGY - BONDING

- 1K-Epoxies
- 2K-Epoxies
- 2K-Methacrylates
- Structural 2K-Polyurethanes
- Silane-epoxy hybrids
- Silicone
JOINING TECHNOLOGY - BONDING

- One sided joining technology
- Various materials can be fit together
- To cure the adhesive the paint shop oven is needed
## JOINING TECHNOLOGY - BONDING

<table>
<thead>
<tr>
<th>Body in White / Stamping</th>
<th>Structure Bonding</th>
<th>Gapfiller Anti Flutter</th>
<th>Hem Flange</th>
<th>NVH</th>
<th>Cosmetic Sealer</th>
<th>Sealing</th>
<th>Reinforce</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bead Application</td>
<td><img src="image1.png" alt="Image" /></td>
<td><img src="image2.png" alt="Image" /></td>
<td><img src="image3.png" alt="Image" /></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Air Swirl E-Swirl</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flatstream</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shovel Gun MOG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multinozzle</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Airless</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jetstream</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2Part bead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
JOINING TECHNOLOGY – FLOW DRILLING

1. Speed and force, heat up the material
2. Penetration of the material – Flow Drilling
3. Molding of cylindrical rim hole
4. Thread forming without cutting action
5. Driving through the material
6. Tightening of the screw

Source: EJOT
JOINING TECHNOLOGY – FLOW DRILLING

- One sided joining technology
- Good performance in all directions
- Various materials can be fit together

Source: EJOT
JOINING TECHNOLOGY – SELF-PIERCE RIVETING

- Two sided joining technology
- Good performance in all directions
- Various materials can be fit together

Source: Henrob
JOINING TECHNOLOGY - SPOT WELDING

- Two sided joining technology
- Good performance in all directions
- Similar materials can be fit together

Source: Spot Weld Theory (GM)
JOINING TECHNOLOGY - SCREW FASTENING

- One sided joining technology
- Good performance in all directions
- Similar materials can be fit together

Example Daimler Roof Fastening (after paint) with Adhesive and Screws
HYBRID JOINING - EXAMPLES

<table>
<thead>
<tr>
<th>Process</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot Weld</td>
<td>1287</td>
</tr>
<tr>
<td>Clinching</td>
<td>164</td>
</tr>
<tr>
<td>SPR</td>
<td>1615</td>
</tr>
<tr>
<td>FDS</td>
<td>230</td>
</tr>
<tr>
<td>Laser</td>
<td>6</td>
</tr>
<tr>
<td>Adhesive</td>
<td>100</td>
</tr>
</tbody>
</table>
HYBRID JOINING - EXAMPLES

<table>
<thead>
<tr>
<th>Method</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot Weld Steel</td>
<td>4441 m</td>
</tr>
<tr>
<td>Spot Weld Alu</td>
<td>316 m</td>
</tr>
<tr>
<td>Clinching</td>
<td>202 m</td>
</tr>
<tr>
<td>SPR</td>
<td>331 m</td>
</tr>
<tr>
<td>FDS</td>
<td>20 m</td>
</tr>
<tr>
<td>ImpAct</td>
<td>80 m</td>
</tr>
<tr>
<td>Adhesive</td>
<td>188 m</td>
</tr>
</tbody>
</table>

- Hot-formed ultra-high-strength steel
- Ultra-high-strength steel
- Steel
- Aluminium

Source: Daimler, Mercedes New C-Class W205
HYBRID JOINING - EXAMPLES

Source: Toyota, Toyota Lexus RC
HYBRID JOINING - REASON & CHALLENGES

- Significant strength improvement with Hybrid Joining

Static shear force of different joining technologies
Example: Steel ZStE 340, sheet thickness 1+1 mm

- Shear tension

<table>
<thead>
<tr>
<th>Joining Technology</th>
<th>Maximum Force in [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistance spot welding</td>
<td>F</td>
</tr>
<tr>
<td>FDS + Bonding</td>
<td>F</td>
</tr>
<tr>
<td>Bonding</td>
<td></td>
</tr>
<tr>
<td>Laser welding</td>
<td></td>
</tr>
<tr>
<td>Self-pierce riveting</td>
<td></td>
</tr>
</tbody>
</table>

Source: DVS F. Lange, DLR
HYBRID JOINING - REASON & CHALLENGES

- Significant strength improvement with Hybrid Joining

- Static tensile shear strength of different joining technologies

- Peel tension

- Maximum Force in [kN]

- Joining Technology

- Bonding
- FDS
- Resistance spot welding
- Self-pierce riveting
- FDS + Bonding
- Laser welding
HYBRID JOINING - REASON & CHALLENGES

Challenges in terms of joining technology

- Multi Material Design MMD
- Layer structure
- Accessibility
  - One-sided
  - Two-sided
- Corrosion
  - Contact corrosion
- Aging impacts
  - Cyclical stress
  - Temperature
  - Environmental
- Strength requirements
  - Elastic joint
  - Rigid joint
- Costs
- Production requirements
  - Systems technology
  - Cycle time
  - Reproducibility
- Detachability
  - Detachable
  - Hardly detachable
  - Undetachable
- Number of layers
  - Process time
- Thermal expansion
- Electrochemical potentials
- Mechanical properties
SAFETY FIRST

- Ear protection
- Eye protection
- Electromagnetic fields
  - Resistance welding causes electromagnetic fields. For safety reasons, persons with cardiac pacemakers and metallic implants are prohibited to join the live demonstrations in the Innovation Center.
- Prohibition of photography
  - Taking of photos is generally prohibited. Thank you for your understanding.
10:15 AM
KEYNOTE SPEECH, PART 1

Break & allocation of groups for keynote speeches