MECHANICAL FASTENING SOLUTIONS
FOR BATTERY TRAYS

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AGENDA

1. A Look Through the 3 Generations of EV Architecture
2. Mechanically Attached Fastening
3. Water Ingress Protection
4. Press Hardened Steel
5. Fasteners in Closed Sections
6. Key Takeaways
A LOOK THROUGH THE 3 GENERATIONS OF EV ARCHITECTURE
GENERATION 1 – SKATEBOARD

- Battery Tray underneath body frame
- Previous generation, still utilized

Rivian RT-1

Extruded Aluminum Sides

Steel Cover

Steel Bottom
GENERATION 2 – STRUCTURALLY INTEGRATED

• Battery Tray integrated structurally with body frame
• Current Generation

Audi e-tron GT
Integration of the high-voltage battery in the body structure
02/21

Battery Tray
GENERATION 3 – VEHICLE INTEGRATED

- Improvements in battery range/charging efficiency
  - Batteries infiltrating more spaces in a vehicle (i.e., Doors)
- Concern for occupant safety
  - Batteries becoming more structural
- Consideration for recycling of battery trays
- Material trends:
  - More optimization of cost
    - Increased use of high-strength steels
  - Lightweighting of components to continue
    - Increased use of alternative materials (aluminum, magnesium)
- Increased use in mechanically attached fasteners
FASTENING CHALLENGES

• Material Applications
  • New materials being introduced
  • Thinner Materials expected

• Ingress Protection
  • Requirements for ingress protection not fully being realized
  • Testing on a component level versus assembly level

• Application access
  • Long extrusions being used
  • Closed Access

• Load Bearing Capabilities

• Electrical conductivity
MECHANICALLY ATTACHED FASTENING
Global Leaders in Mechanically Attached Fasteners
THE PENN ENGINEERING ADVANTAGE

Technical Advisory and OEM and Tier
Global field engineering and direct sales engineers

Manufacturing
Global manufacturing capabilities in local markets

Application Engineering Support
Global application engineering experts and full test lab capabilities

After Sales Technical Support
Full, ongoing technical support and on-site training as required
# MECHANICALLY ATTACHED FASTENERS (MAF)

<table>
<thead>
<tr>
<th><strong>Internal Thread</strong></th>
<th><strong>External Thread</strong></th>
<th><strong>Self-Pierce</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Riveting</strong></td>
<td><strong>Clinching</strong></td>
<td><strong>Self-Pierce</strong></td>
</tr>
</tbody>
</table>
RIVETING

Link to video: https://www.profil-global.com/products/rnd/
CLINCHING

Link to video: https://www.profil-global.com/products/ebf/
SELF-PIERCING NUT

Link to video: https://www.profil-global.com/products/mhn/
SELF-PIERCE STUD

Link to video: https://www.profil-global.com/products/sbf/
WATER INGRESS PROTECTION
INGRESS PROTECTION

• Based on ISO 20653
  • IP67 – Temporarily submerged in water (30 minutes)
  • IP69K – Protection against high-pressure/steam jet cleaning

• Current process:
  • Submerge assembly in a large water bath
  • Wait 30 minutes and look for bubbles
  • Disassemble tested assembly
  • Look for water

• This process is quantifiable through counting bubbles expelled by the battery pack
CLARIFICATION OF FAILURE

Failure

- Water bead
- Water drop

Pass

- Water bead
INGRESS PROTECTION

• Internally developed standard for leak testing MAF
• Developed with industry partner Inficon
• Quantifies leak resistance through vacuum method referencing Helium gas
• Available for industry use, please contact us
INGRESS PROTECTION

- Vacuum method referencing helium
  - Connect helium detector to outgoing port
  - Engage vacuum
  - Provide Helium to leak area
  - Read test value

<table>
<thead>
<tr>
<th>Request</th>
<th>mbar·l/s</th>
<th>cm³/s</th>
<th>cm³/min</th>
<th>l/min</th>
<th>l/h</th>
<th>ml/min</th>
<th>sccm</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water tap drips</td>
<td>10⁻⁰</td>
<td>10⁻⁰</td>
<td>6·10⁻¹</td>
<td>6·10⁻²</td>
<td>3.6·10⁰</td>
<td>6·10¹</td>
<td>6·10¹</td>
<td>Water tap drips</td>
</tr>
<tr>
<td>Watertight</td>
<td>10⁻¹</td>
<td>10⁻¹</td>
<td>6·10⁻⁰</td>
<td>6·10⁻³</td>
<td>3.6·10⁻¹</td>
<td>6·10⁰</td>
<td>6·10⁰</td>
<td>1 cm³ gas loss in 10 s</td>
</tr>
<tr>
<td>Oil-tight</td>
<td>10⁻²</td>
<td>10⁻²</td>
<td>6·10⁻¹</td>
<td>6·10⁻⁴</td>
<td>3.6·10⁻²</td>
<td>6·10⁻¹</td>
<td>6·10⁻¹</td>
<td>Water tap does not drip</td>
</tr>
<tr>
<td>Bacteria Proof</td>
<td>10⁻³</td>
<td>10⁻³</td>
<td>6·10⁻²</td>
<td>6·10⁻⁵</td>
<td>3.6·10⁻³</td>
<td>6·10⁻²</td>
<td>6·10⁻²</td>
<td>&lt;1 bubbles per second</td>
</tr>
<tr>
<td>Gasoline Proof</td>
<td>10⁻⁴</td>
<td>10⁻⁴</td>
<td>6·10⁻³</td>
<td>6·10⁻⁶</td>
<td>3.6·10⁻⁴</td>
<td>6·10⁻³</td>
<td>6·10⁻³</td>
<td>1 cm³ gas loss in 160 min</td>
</tr>
<tr>
<td>Gas Tight</td>
<td>10⁻⁵</td>
<td>10⁻⁵</td>
<td>6·10⁻⁴</td>
<td>6·10⁻⁷</td>
<td>3.6·10⁻⁵</td>
<td>6·10⁻⁴</td>
<td>6·10⁻⁴</td>
<td>1 cm³ gas loss in 26 h</td>
</tr>
<tr>
<td></td>
<td>10⁻⁶</td>
<td>10⁻⁶</td>
<td>6·10⁻⁵</td>
<td>6·10⁻⁸</td>
<td>3.6·10⁻⁶</td>
<td>6·10⁻⁵</td>
<td>6·10⁻⁵</td>
<td>1 cm³ gas loss in 12 days</td>
</tr>
</tbody>
</table>

Meaning of leakage rates, $\Delta p = 1\text{ bar}$:

<table>
<thead>
<tr>
<th>Steel</th>
<th>$\approx \ 5 \cdot 10^{-3} \text{ mbar·l/s} \approx 1 \cdot 10^{-3} \text{ mbar·l/s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>$\approx 5 \cdot 10^{-5} \text{ mbar·l/s} \approx 1 \cdot 10^{-5} \text{ mbar·l/s}$</td>
</tr>
</tbody>
</table>

Correlation between IP67 and IP69k and panel substrate:

Demonstrations at our booth or appointment!
INGRESS PROTECTION FASTENERS

RND Cap Nut
No special seals required

EBF - Watertight
Clinch Stud
PRESS HARDENED STEEL
PRESS HARDENED STEELS

**Direct process**
- Coil
- Heating
- Forming, hardening and quenching
- Finished component
  - Few process steps
  - Short cycle times

**Indirect process**
- Coil
- Forming
- Heating
- Quenching, calibrating and hardening
- Finished component
  - Complex geometries
  - Tool-friendly
Steel is softest during forming stage and can easily self pierce.

Fastener temperature elevates but does not temper due to cooling.
PRESS HARDENED STEELS - DIRECT

SMP nut applied at 600°C sheet temperature
PRESS HARDENED STEELS - DIRECT

SBF

SMP
PRESS HARDENED STEELS

- Direct process:
  - Coil
  - Heating
  - Forming, hardening and quenching
  - Finished component
  - Few process steps
  - Short cycle times

- Indirect process:
  - Coil
  - Forming
  - Heating
  - Quenching, calibrating and hardening
  - Finished component
  - Complex geometries
  - Tool-friendly
PRESS HARDENED STEELS - INDIRECT

Coil → Forming → Heating → Quenching, calibrating and hardening → Finished component

Cooling circuit

Uncontrolled fastener hardness

Fastener to be installed during quenching phase or through secondary process
Process not limited to fastener
PRESS HARDENED STEELS - INDIRECT

Indirect process

Coil ➔ Forming ➔ Heating ➔ Quenching, calibrating and hardening ➔ Cooling circuit ➔ Finished component

Fastener to be installed during quenching phase or through secondary process
Process not limited to fastener
PRESS HARDENED STEELS - INDIRECT

Specialized Fasteners designed

RND-S

Square RSE

Flush surface
FASTENERS IN CLOSED SECTIONS
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KEY TAKEAWAYS
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• EV architecture is evolving needing solutions from fasteners
• Mechanically attached fasteners are highly tailored solutions to many fastening problems
• Water ingress protection is possible through mechanically attached fasteners
• Attachment to a wide variety of materials is possible
• Applications in less accessible areas is possible, working with customers is key
• Development of Special Fasteners for Electrical Conductivity aids in application design
FOR MORE INFORMATION

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