Cell Welding in AVL Battery Development Process
18/11/2020, BI-REX - Bologna
Process Innovation and Industrialization

Francesco Mastrandrea
Index

AVL Worldwide Battery Competencies & Facilities

Battery Thermal Runaway and Importance of Cell Welding

Welding Development Process

New Innovation Center and Virtualization
**Facts and Figures**

<table>
<thead>
<tr>
<th>Founded</th>
<th>Employees Worldwide</th>
<th>Of Turnover Invested in Inhouse R&amp;D</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948</td>
<td>11,500</td>
<td>10%</td>
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</table>

<table>
<thead>
<tr>
<th>Years of Experience</th>
<th>Engineers and Scientists</th>
<th>Granted Patents in Force</th>
<th>Export Quota</th>
</tr>
</thead>
<tbody>
<tr>
<td>70+</td>
<td>65%</td>
<td>1,500</td>
<td>96%</td>
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</table>

**Global Footprint**

- Represented in 26 countries
- 45 Affiliates divided over 93 locations
- 45 Global Tech and Engineering Centers (including Resident Offices)
AVL supports **battery development** projects from first drawing to SOP with **battery module and pack development services**, as well as **BCU software** and **hardware**.
Global Battery Competence Team and Italian Branch

- 30 engineers on battery pack
- Full development capabilities
- 800 kW Climate container
- 50 battery prototypes for year
- Involved in 400V and 800V projects

> 400 engineers worldwide
> 10 years of experience

Battery prototype build and test facilities available

*Headquarters in Graz
Vehicle Recalls in 2020 for Battery Problems

Hyundai NZ recalls Kona electric car due to battery fire risk

Ford Kuga recall: Ford finds fix for faulty PHEV battery pack

BMW recalls plug-in hybrid models due to fire risk

Cell Welding influencing the electrical resistance and it could represent a trigger for Thermal Runaway
Conventional vs. Electrification - Production & Processes

<table>
<thead>
<tr>
<th>Comparison</th>
<th>Modularity</th>
<th>Maturity</th>
<th>Volatility</th>
<th>Quality</th>
<th>Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product architecture</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Assembly concepts</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>OEM Assembly Standards</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Material Cost</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Component technology Concepts</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Quality Risks</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Supply Chain</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Welding technologies &amp; Quality</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Gluing Processes</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Supplier Structure</td>
<td>3</td>
<td>4</td>
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<td>4</td>
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<tr>
<td>Process time</td>
<td>3</td>
<td>4</td>
<td>3</td>
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</tbody>
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Further Challenges for Traction Batteries:

- **Cost**
  - Dominance of cell costs

- **Safety & Quality Challenges**
  - Multiple, high-volume manual assembly steps
  - High Volume cell testing
  - EoL test concepts

- **Supply Chain Challenges**
  - Make-or-buy module / pack
  - Non-automotive supplier development

**Welding in Electrification is not robust yet as in the Conventional Vehicle**
## Cell2Cell (Module) Manufacturing Core Technologies

<table>
<thead>
<tr>
<th>Core Process</th>
<th>Issue/Challenge</th>
<th>Solution Approach</th>
<th>Activity during Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cell Testing</td>
<td>Automation to achieve cycle times &amp; reliability</td>
<td>High-speed reading &amp; automated handling of cells</td>
<td>Principle tests carried out within automated cell testers</td>
</tr>
<tr>
<td></td>
<td>Automated check against outgoing inspection values</td>
<td>Big data competence</td>
<td>Currently built up</td>
</tr>
<tr>
<td>Stacking</td>
<td>Handling &amp; alignment</td>
<td>Process (IP) development</td>
<td>Testing of production principle</td>
</tr>
<tr>
<td>Cell gluing</td>
<td>Application of correct amount / component tolerances</td>
<td>Application development w/ suppliers</td>
<td>Application development w/ suppliers</td>
</tr>
<tr>
<td>Welding</td>
<td>Cycle times, weld quality</td>
<td>Build-up of specific welding know-how, partnerships</td>
<td>Welding equipment &amp; parameter tests</td>
</tr>
<tr>
<td>EOL testing</td>
<td>Cycle times vs. investments</td>
<td>EOL testing time minimization</td>
<td>Incremental test program development</td>
</tr>
</tbody>
</table>

### Areas of Innovation
- Welding
- EOL testing
Cell to Cell Welding Technologies Landscape

**Laser Welding**
- **Pros**
  - High flexibility (thickness, mat. & combinations)
  - High speed operation
  - Different welding seams geometries
  - All cell types
  - Low maintenance efforts
  - Very high investment
- **Cons**

**Micro Tig Welding**
- **Pros**
  - Prototype production
  - Low investment
  - Long tact time (1 sec)
  - Less electrical connection area
  - High cleaning efforts
  - Mainly cylindrical cells
  - Limitation busbar thickness
- **Cons**

**Resistance Welding**
- **Pros**
  - Very low investment
  - Longer tact time (1 sec)
  - Electrode cleaning
  - Heat impact on cells
  - Mainly cylindrical cells
  - Limitation busbar thickness
- **Cons**

**Ultrasonic Welding**
- **Pros**
  - Flexible material thickness
  - Low heat impact
  - High holding force
  - Sonotrode cleaning
  - High investment
  - High efforts clamping/fixation
- **Cons**

**Wire Bonding**
- **Pros**
  - No melting of cell pole
  - Flexible material thickness
  - Low heat impact
  - Less electrical connections area
  - Cleanliness requirements
  - High investment
  - High efforts clamping/fixation
- **Cons**
Welding Development Process

III Loop

- Welding test on deep charged cell with original busbar design
- Setup final welding test and analysis
- Weld seam analysis: Go/No-Go
- Welding test on sample parts
- Analysis and parameter optimization (Repeat tests if necessary)

I Loop

- Define possible welding parameters to achieve the requirement
- Experimential test and final setup and welding analysis
- Analysis and parameter optimization (Repeat tests if necessary)

II Loop

- Welding test on deep charged cell with original busbar design
- Setup final welding test and analysis
- Weld seam analysis: Go/No-Go
- Welding test on sample parts
- Analysis and parameter optimization (Repeat tests if necessary)
Component Testing & Welding Assessment
Battery Development

Characterization
Adhesive, Foam & Sealing

Hardness testing & curing time
Shrinkage & thermal expansion
Tensile Test
Compression Tests
Pull, Shear, Peel Tests

Weldability test

Welding test on machine
Micrograph Analysis
Shear peel test
Heat impact measuring
Hardness Profile

Simulation Validation in Component Level

Lap-Shear Test (EN 1465)
Bonding Force Evaluation
Compatibility Test
Surface tension and pre-treatment

Qualification norms: BS EN 15614, EN 287, EN ISO 9606, BS 4872, ASME Section IX, CAA A8-10
Fabrication norms: PD5500, EN 13480, EN 13445, BS 4515, EN 1011, BS5400, DIN 6700, ASME B&PV Section VIII, Section III, Section XI, B31.1, B31.3, B31.4, B31.8, AWS D1.1, API 1104, API 510, API 620

Public

Francesco Mastrandrea | AVL Italy | 18 novembre 2020 |
AVL Battery Innovation Center: Fusion of Function & Process Development

- Flexible center for production-oriented manufacturing of proto battery modules and packs
- Process development for specific assembly procedures in battery production
- Close loop feedback to product development (DfM - Design for manufacturing)
- Serve higher volumes in A- & B-samples
- Provide capacity for field test fleets, racing series and C-samples
- Provide industrialized designs and processes “ready for ramp-up”
- Leveraging of Engineering Business for battery development
- Verify Eco-Design products in respect to recycling and cost
Virtual Steps in Industrialization for Welding Process Validation in Manufacturing

- VR concept review
- Preview of steps
- Safe worker training

- 2-part head / gripper design
- additive manufactured Grippers
- Robots within A-sample assembly

- Innovative processes
- Rapid Tooling
- VR manufacturing instructions
- Worker training on new parts or hazard steps
Thank you

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