Accelerating the Development of Aluminium Lightweighting Solutions for Body-In-White and Crash Management Systems

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Agenda

- Company Introduction
- Need for innovative aluminium lightweight solutions
- Market growth of aluminium sheet & extrusion
- Driving innovation in the Constellium University Technology Center
- Conclusion
Constellium: a leader in innovative aluminium solutions for the automotive, aerospace & packaging industries

2015 key figures

- **Over 10,000** full-time employees
- **€5.2 billion** in sales
- **22** manufacturing sites
- **C-TEC**, our world-class **Technology Center**

Headquartered in **Amsterdam**, The Netherlands. Corporate offices in **Paris**, France, **Zurich**, Switzerland and **New York**, USA
World-class Research and Technology capabilities

- Alloy development
- Component design
- Process development, including joining technologies
- Simulation
- Prototyping at scale
- Testing
- Technology transfer for production

C-TEC
Research & Technology Center

Constellium UTC
Brunel University London

Production/support
Global manufacturing network
The lightweighting agenda, driven by regulation

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The challenge is even greater

We believe aluminium has an unrivalled “benefit/cost” position

5-fold Increase in global Body-in-White market expected

Global FRP Al-BiW market forecast act. 2012 – 2020 (kt)

CAGR ’12 – ’20

Asia +38%

US +43%

Europe +15%

* Outlook excluding any major shift for a new high volume model
Source: Constellium internal analysis
### Constellium Auto Body Sheet R&D by product families

<table>
<thead>
<tr>
<th>Product Family</th>
<th>Key Product Property Development Needs</th>
</tr>
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<tbody>
<tr>
<td></td>
<td><strong>Formability</strong></td>
</tr>
<tr>
<td>Outer Skin</td>
<td>Main development need to allow demanding designs</td>
</tr>
<tr>
<td>Closure inner</td>
<td>Main development need to allow part integration and rationalization</td>
</tr>
<tr>
<td>Main Body Structure &amp; Crash</td>
<td>Current alloy formability good Further options with strength/formability compromise possible</td>
</tr>
<tr>
<td>Safety Cell</td>
<td>Hot stamping technology can be used for high strength parts</td>
</tr>
</tbody>
</table>
Confidential

Constellium C-TEC: New product prototyping at industrial scale

Alloy prototyping at full industrial scale with pilot casting units

Alloy prototyping with hot and cold semi-industrial rolling mills
Constellium C-TEC:
Key customer joint developments of new technologies

- **Full scale evaluation**
  - Equipment to better understand interactions between our products and new OEM processes

- **Improving forming simulation**
  - Working to make forming simulation more reliable (feasibility, springback)

- **Support in welding technologies**
  - Feasibility & optimization trials
  - New technology investigation

Friction stir welding of components

AI/Steel joining (CMT)
Estimated growth in extruded & forged aluminium products

Average Kg’s per vehicle

- Wrought aluminium content increasing from 140 kg in 2012, 180 kg in 2020*
- 14% of the wrought aluminium content used as extruded & forged product*
- 2025 assumes 200 kg of wrought aluminium content, 16% as extruded/forged and a vehicle forecast of 20.5 million**

*Ducker 2012 – EAA aluminium penetration in cars

**IHS Automotive 2015 – Trends in European light vehicle production

How does this translate to structural components?
Development & implementation strategy

- Lightweighting using extrusions and forged products made from a range of novel high performance 6xxx alloys and production processes

- Constellium University Technology Center (UTC) in partnership with Brunel University London will provide:
  - Reduced development times by at least 50%
  - Closed loop recycling & alloy compatibility with the main sheet products
  - A “copy & paste” approach to industrialization, to de-risk technology transfer
  - A dedicated team of 15 researchers, engineers and technicians
  - Sponsorship of research fellows/PhD’s & training of our own engineers/technicians
  - The full innovation value chain
Constellium University Technology Center
Brunel University London

DC casting – alloy development & casting technology

- 6” and 7’ hot top billet DC caster
- 2m long log capability
- Double drop capacity with one furnace charge
- Compatible with Brunel University melt conditioning technology
Extrusion – thermo-mechanical processing & extrusion design

- 16MN extrusion press with puller
- 6” and 7” container diameter
- Air, spray and standing wave quench box
- 14m cooling table with stretcher cold saw
Linking the strategic automotive alloy portfolio to component manufacture

- **Ultra High Strength >460 MPa 6xxx Forgings**
- **Ultra High Strength >400 MPa 6xxx Bumpers**
- **High Performance Structural Body C20 to C24**
- **High Performance Crush C26 to C28, C3…**

- **Cost Competitive Solutions**
  - Robust Manufacturing Processes
  - Meets Specification/Quality Standards

- **High Strength, Corrosion Resistance & Good Ductility**
- **Excellent Crush & Corrosion**

**Key Enablers Casting & Extrusion**
- Alloy & Microstructural Design
- Process Design & Innovation - Casting & Extrusion Practice
- Die Design – Shape, Section Complexity & Tolerances
- Thermo-mechanical Ageing

**Key Enablers – Component Manufacture**
- Design Methodologies/Systems - To Provide Efficient Part Design
- Process Design & Innovation – Fabrication & Joining Technologies
Design for crush

Shape complexity vs Alloy strength

- C20
- YS 200 MPa

- C22
- YS 220 MPa

- C24
- YS 240 MPa

- C26
- YS 280 MPa

- C28
- YS >300 MPa

Increasing shape complexity/tolerances at higher strength

Defined crush performance
Design for crush

- Provide a “design guide” in order to optimize both alloy selection (strength & ductility) and the geometrical features of the crush component to provide a crash absorbing structure at the desired weight and functional performance.
- A methodology to link the crush performance to material ductility and profile design has been developed.
- Key process & geometrical features to provide class A crush performance are being investigated.

Aramis (Image) Correlation System for deformation measurement

Key laboratory tests to quantify material ductility

Crush performance = material ductility + crush box design
HSA6 strength development: hollow profiles

> Strength UTS - MPa

- 425 MPa
- 400 MPa
- 350 MPa

> Alloy Composition & Processing Technology

**Conventional High Strength 6xxx Alloys**

**New High Strength 6xxx Alloys – HSA6**

**Shape Complexity/Strength Compromise**

**Ultimate 6xxx Strength Capability?**
LEAAST – Innovate UK supported research program

Optimization of front CMS by introducing Constellium’s HSA6 and C28 alloys

- CAD design and joining optimization
- Weight saving of the fully assembled CMS of 30%
- Better performance in different crash scenarios (FEA simulations)

<table>
<thead>
<tr>
<th>Benchmark Case series design</th>
<th>RCAR bumper, 10 kph Distance beam to radiator</th>
<th>RCAR structure, 16 kph: Max. Intrusion, Max peak force crashbox</th>
</tr>
</thead>
<tbody>
<tr>
<td>6,462 kg</td>
<td><img src="image1" alt="RCAR bumper, 10 kph Distance beam to radiator" /></td>
<td><img src="image2" alt="RCAR structure, 16 kph: Max. Intrusion, Max peak force crashbox" /></td>
</tr>
<tr>
<td>HSA6 &amp; C28 alloys welded</td>
<td><img src="image3" alt="Image" /></td>
<td><img src="image4" alt="Image" /></td>
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- Weight saving of the fully assembled CMS of 30%
- Better performance in different crash scenarios (FEA simulations)
Advanced Metals Processing Center

- Stretching & roll forming
- Free-form bending
- Magnetic pulse forming & welding
- Fusion welding cell – conventional MIG to CMT
- Riveting & bonding
- GOM & ARAMIS systems for dimensional characterisation & strain measurement
- Multi-axial fatigue rig to test full-size chassis & sub-frame parts
- Simple machine shop, turning/milling/drilling/sawing (incl. mitre cut)
Advanced processing of HSA6 for higher strength

- Develop the strongest 6xxx series automotive alloys on the market & reach highest possible strength
- Apply advanced processing (TMA) to HSA6 for further 15% CMS lightweighting vs conventional HSA6 solutions
- Design CMS superior to that of conventional 6xxx & 7xxx series alloys
- Optimize 6xxx composition and combine with novel forming technics
- Develop full-scale prototype components for validation using the Constellium UTC facilities
Joining of high-strength extrusions by Cold Metal Transfer (CMT)

- HSA6 welded in the as-extruded (T4) condition then subsequently peak-aged (T6), shows a significant improvement in HAZ strength properties compared with material aged to T6 then welded. This effect is more pronounced with CMT.

- At equivalent weld penetration, the CMT welding process injects significantly less heat than traditional MIG arc welding.
Pulse magnetic forming & welding

- Technology
  - High rate current discharge in a coil
  - Shaping or joining of aluminium

- Forming & welding of 6xxx automotive alloys
  - Locally shape & calibrate profiles (deep drawing)
  - Get rid of HAZ to access full strength of the materials
  - Join dissimilar materials

- Welding of aluminium coupons
  - No visible interface between materials
  - No hardness loss in the alloys (i.e. no HAZ)
Conclusion

- Stronger, more ductile aluminium alloys are expected to have a crucial role to play in vehicle lightweighting in all products forms.

- Innovation-led rapid prototyping at “scale” is essential in reducing time to market and de-risking technology transfer.
  - Constellium University Technology Center provides industry-first capability.

- Investment in people to support technology delivery within R&D units and production facilities is vital.