Aluminium
Light-weighting for transportation

Les alliages d’aluminium pour l’automobile et l’aéronautique: performances et perspectives

Bruno CHENAL

Nancy, 8 Juin 2016
Constellium: a long and rich experience in aluminium

More than a century of growth

- **1855**
  - Pechiney

- **1888**
  - Alusuisse

- **1902**
  - Alcan

- **2000**
  - Alcan Aluminium Limited merges with Algroup/Alusuisse

- **2003**
  - Alcan Inc. acquires Pechiney

- **2007**
  - Rio Tinto acquires Alcan

- **2011**
  - January
    - Rio Tinto sells 51% of Alcan Engineered Products to Apollo, 10% to FSI and keeps the remaining 39% stake
  - May
    - Alcan Engineered Products is renamed to Constellium

- **2013**
  - January
    - Constellium commences trading on the New York Stock Exchange and NYSE Euronext Paris
  - May
    - Constellium acquires Wise Metals

- **2015**
  - January
    - Constellium acquires Wise Metals
Constellium is a leader in innovative aluminium-based solutions

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
Constellium serves blue-chip customers

Aerospace
- Airbus Group
- Bombardier
- Embraer
- Pilatus
- KAI
- Boeing
- Dassault Aviation
- SpaceX
- Lockheed Martin

Packaging
- Rexam
- Crown
- Amcor
- AB InBev
- Ardagh Group
- Ball
- Can-PACK S.A.
- Coca-Cola

Automotive
- Audi
- BMW
- FCA
- Ford
- PSA Peugeot Citroën
- Mercedes-Benz
- GM
- Jaguar
- Land Rover
- Porsche
- Valeo
- Tesla
Agenda

- Requirements for new materials in transportation
- Recent and ongoing developments of aluminium in automotive applications
- Recent and ongoing developments of aluminium in aerospace applications
Summary

- Requirements for new materials in transportation
- Recent and ongoing developments of aluminium in automotive applications
- Recent and ongoing developments of aluminium in aerospace applications
Global market for flat rolled sheet in BiW

Key drivers for growth in aluminium FRP in BiW worldwide

1. Steel to all-aluminium conversion of big volume US OEMs.
2. Incremental conversion steel to aluminium in hang-on parts, then structures at all OEMs.
3. Geographic expansion of European Premium Brand OEMs using aluminium.
Aluminium in the Body-in-White

**Incremental change**
Closures and hang-on parts first, then parts in body structure

- Moderate weight saving
- Moderate CapEx
- Low risk, reversible decisions
- Need for multi-material joining & assembly

**Step-change**
All-Aluminium / Aluminium Intensive Vehicle Design

- Big weight savings
- Large CapEx & manufacturing changes
- Step-change in supplier volumes
- Need for high-productivity, all-Al assembly line

2015 Ford F-150
**Constellium Aluminium in Automotive BiW**

We supply key OEMs the full range of aluminium sheet and extruded products.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>A3</th>
<th>A8</th>
<th>F-150</th>
<th>Model S</th>
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<tr>
<td>A</td>
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Some of the vehicles where we supply Constellium aluminium for structural parts, closure inners and/or outer skin panels.
Constellium’s BiW Portfolio is based on Cu-free 6xxx (AlMgSi) and 5xxx (AlMg) alloys.

**SURFALEX®**
No compromise with Aesthetics!

**FORMALEX®**
No compromise with Design!

**STRONGALEX® & ULTRALEX®**
No compromise with Light-weighting!

**SECURALEX®**
Crash crushable alloy for structural parts
Higher strength alloy families exist but in general imply lower ductility (formability)
Summary

- Requirements for new materials in transportation: weight/cost benefits
- Recent and ongoing developments of aluminium in automotive applications
- Recent and ongoing developments of aluminium in aerospace applications
AEROSPACE

Today, aerostructures are more hybrid. The proportions of the different materials are re-assessed for each new aircraft.

Historical reminder of main aircraft programs

<table>
<thead>
<tr>
<th>% Composite</th>
<th>Date of first flight</th>
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<tbody>
<tr>
<td>53%</td>
<td>2009</td>
</tr>
<tr>
<td>25%</td>
<td>2005</td>
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<tr>
<td>15%</td>
<td>2001</td>
</tr>
<tr>
<td>11%</td>
<td>1994</td>
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Airbus A380, Boeing 787, Airbus A350 XWB, Airbus A380, Airbus A330, Boeing 777, Airbus A320 NEO, COMAC C919, Bombardier CSeries, New Single Aisle Boeing / Airbus

Challenge for new material solutions: Proposal of AIRWARE® solution
Depending on %Cu, Li content, different strengthening precipitates can be obtained.

\( \delta' (Al_3Li) \) spheres

\( \theta' (Al_2Cu) \) plates; tetragonal on plane \( \{100\}_Al \) (if no Ag in alloy)


\( T_1 (Al2CuLi) \) plates; hexagonal on \( \{111\}_Al \) plans

Following Van-Smaalen et al., 1990


Phase diagram source: Constellium Software ProPhase – C. Sigli

Constellium preferred target consists in exploiting the full potential of T1: AIRWARE®

- Multi-phase precipitation systems based on main elements as Al-Li-Cu-Ag-Mg

![Graph showing Al-xCu-yLi at 500°C (-) + metastable at 155°C (-)]

- High damage tolerant dominated area
- High strength dominated area
- Strength-Toughness balanced property
AIRWARE® alloys outperform current aluminum solutions.

AIRWARE® permit to gain weight (acc. to airframer and internal calculations)
- 3-6% weight from density alone (no skin thickness reductions)
- 5-10% weight for replacement at iso-design (optimized local thicknesses)
- 15-25% weight for redesign with Al-Cu-Li alloys

AIRWARE® 2198 Fuselage Sheet
AIRWARE® 2050 Plate

* Compared to 2024 T351
* Compared to 7050 T7451
AIRWARE® technology achieves exceptional balance of properties to meet the specifications of all structures of civil aircrafts.

- **Fuselage skin**: 2098, 2198
- **Stringers for fuselage**: 2195, 2196
- **Frames, Internal**: 2098, 2198, 2050
- **Upper wing skin**: 2195
- **Floor beams, seat tracks**: 2196
- **Central wing box**: 2050
- **Stringers for wing**: 2195, 2296
- **Spars, ibs and stringers**: 2050
- **Lower wing skin**: 2196, 2050

17 Eurocorr 2013 – Estoril – Plenary Lecture - Challenges and recent development in aluminium corrosion resistant alloys for transport applications
Summary

- For lightweighting, materials developments for transportation must meet performance and cost requirements. But step change can be achieved via co-optimization of design, material, manufacturing.

- Driven by the evolution of regulation towards reducing CO2 emissions of cars, and by the competition with other materials in aerostructures, Aluminium has a fantastic but challenging growth opportunity.

- CONSTELLIUM has defined automotive and aerospace as one of his key strategic segments, and is actively addressing those challenges through strong R&D capabilities:
  - Developing an appropriate portfolio of alloys along key technical drivers and pursuing with more step-change concepts
  - Partnering with OEMs to develop affordable solutions
  - All this with sustainability in mind