Aluminium from Cans to Cars

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Innoval Technology is an independent technology provider serving aluminium companies and end-users of aluminium.
Fuel Consumption vs Vehicle Weight
To achieve <100g CO₂ per km curb weight must be <1000kg
The UK Government has set the target that cleaner cars (defined as 'low carbon'; <100g/km) should represent 10% of all car sales by 2012 (DfT 2002).
Jean Albert Gregoire and Aluminium Francais

1934, Aluminium Francais Gregoire (AFG) cast aluminium frame.

1946, VP2 launched as the Dyna (560 kg)

1953-59, Dyna Z (by 1957 steel replaced aluminium)

1948, Dynavia prototype
Spot welded aluminium body on a sheet aluminium floor reinforced with extruded tubes and side sills. The alloy used was similar to AA5754. Panhard manufactured over 50k aluminium intensive cars.

**Dyna Panhard (1954)**

The first production car to use aluminium as a structural material for its body shell. It was powered by a 850 cc two-stroke engine, weighed only 629 kg and could carry six people.
**Description:** Audi Space Frame (ASF)
SOP: 1994
Weight: BIW + closures: 249 kg
Number of parts: 334

**Volume** (cars/year): 16,000 (105,092 by 2002)

**Joining methods:**
- Resistance spot welds: 500
- Clinches: 179
- Self piercing rivets: 1100
- MIG welds: 70 m

**Materials/parts:**
- Extrusions: 47 (14%)
- Castings: 50 (15%)
- Stampings: 237 (71%)

weight saving 500 kg (43%)
231 to 355 g/km
Audi A2 1.2 TDi AIV (80g/km)

- First 4 door 3 litre car (2.99 litres/km)
- Axle mounting frame, control arms and spring struts, brake calipers on the front disc brakes and the brake drums at the rear are aluminium
- Lightweight forged aluminium wheels
- Weighs 825 kg (135 kg lighter than 1.4 TDi)
- The three cylinder aluminium 1.2 litre TDi engines is one of the lightest passenger-car diesel engines at 100 kg
- Produced at 20 cars/day (29,000 produced???)
**Audi A2 ASF (1999)**

**Description:** Audi Space frame:
SOP 1999
Weight: BIW (121 kg) + closures 153 kg
Number of parts: 225
**Volume** (cars/year): scheduled 70,000

**Joining:**
Self piercing rivets: 1800
MIG weld: 20 m
Laser weld: 30 m

**Materials/parts:**
Stampings: 183 (81%)
Extrusions: 22 (10%)
Castings: 20 (9%)

Weight saving 231 kg
119 to 144 g/km (1.2 TDi 80 g/km)
165,000 vehicles built
The VW 1-litre car is so named because of its fuel consumption rating of just 1 litre per 100 km (equivalent to 282 mpg).

The car was produced under contract by the design company Stolfig.

Carbon-fibre-reinforced outer skin tensioned over a magnesium spaceframe

Key issues with magnesium extruded profiles and sheet were cost and the inherent lack of formability at ambient temperature. This was particularly significant for mechanical joining by clinching and self-pierce riveting (SPR).
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Alcan AIVs 1983 to 1993

BL Metro AIV

Six AIV replica British Leyland Metros were built in 1983. The sheet monocoque body structure was built from AA5251 sheet while the closure panels consisted of standard steel components.

Bertone Fiat X1/9 AIV

Five AIV replica Bertone Fiat X1/9s were built in 1986 using AA5251 sheet for the monocoque and AA6010 for the closure panels.

Ford Taurus/Sable AIV

A build of 40 Mercury Sable AIVs was completed in 1993 using AA6111 sheet for closure panels and AA5754 sheet for the monocoque structure. The structure was not redesigned yet a weight saving of 46% was achieved.
## Ford Taurus/Sable Replica AIV (1992)

<table>
<thead>
<tr>
<th>Component</th>
<th>Steel</th>
<th>Aluminium</th>
<th>Weight Saved</th>
<th>%Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Structure (kg)</td>
<td>271</td>
<td>145</td>
<td>125</td>
<td>46</td>
</tr>
<tr>
<td>Hood, deck &amp; fenders</td>
<td>41</td>
<td>17</td>
<td>24</td>
<td>58</td>
</tr>
<tr>
<td>Front and rear doors</td>
<td>60</td>
<td>36</td>
<td>24</td>
<td>40</td>
</tr>
<tr>
<td><strong>Total body-in-white</strong></td>
<td><strong>372</strong></td>
<td><strong>199</strong></td>
<td><strong>173</strong></td>
<td><strong>47</strong></td>
</tr>
<tr>
<td>Torsional rigidity (Nm/rad)</td>
<td>575</td>
<td>855</td>
<td></td>
<td>49</td>
</tr>
<tr>
<td><strong>Total vehicle</strong></td>
<td><strong>1488</strong></td>
<td><strong>1315</strong></td>
<td><strong>173</strong></td>
<td><strong>12</strong></td>
</tr>
</tbody>
</table>

**Description:**
Sheet unibody structure  
SOP: 2003  
**Weight:** painted BIW 295 kg  
**Volume** (car / year): 30,000  

**Materials / parts:**
- Castings: 15 (5 %)  
- Extrusions: 22 (7 %)  
- Stampings: 273 (88 %)  
- Curb weight: -200 kg  
- 249 to 299 g/km CO$_2$

**Joining methods:**
- Adhesive bonding (114 m)  
- Self piercing rivets (3195)  
- Clinches: 110  
- MIG welds: 2 m  
- Blind rivets: 22

**Special characteristics:**
- 40 % lighter than steel  
- 60 % stiffer than predecessor  
- Suitable for high volume production (> 100,000 units per year)

- Body-in-White weight saving: ~ 54%
- Final finished vehicle weight saving: ~40%
- Vehicle weight: 909Kg
- Torsional Stiffness - Increased by 54%
- Bending Stiffness - Increased by 4%

Mondeo/Contour sized vehicle with mass reduced from 1508 to 909kg.
3L/100km vehicle maintaining all safety, durability, NVH and other functional attributes. Achieved through reduction in body structure, closure panel, seat, instrument panel trim etc., chassis, power train and fuel weight

H J Cornille, J C Weishaar and C S Young, The P2000 Body Structure, SAE 982405

Jaguar X-type 2.0D
1575 kg
149 g/km

Disruptive Technologies for Light Metals, April, 2006
Myths of Aluminium Automotive Structures

• Aluminium is difficult to spot weld reliably and consistently

• Bonding of aluminium requires high modulus adhesives and aerospace quality pretreatment systems

• Aluminium sheet requires surface texturing to enhance formability

• Aluminium sheet requires a surface stabilisation chemical treatment

• Aluminium intensive vehicles require purpose built finishing lines
LME Peaks never exceeds 2 year period (time required to balance demand & supply).
Since 1989 & fall of the “Iron Curtain", market has developed into a Global Market.
Fluctuations are balanced in a shorter time, resulting in a more stable market.
LME Trend line continues downwards towards LWV target of $1000 per metric ton.

Need to approach $1000 per tonne to achieve cost parity with steel at $500 per tonne.
The average cash LME aluminium price for 2005 was 1899 $/t
The median forecast for LME cash aluminium price in 2006 is 2090 $/t
For 2007 the forecast median is 1875 $/t
### Material cost analysis – cost per metric tonne

<table>
<thead>
<tr>
<th>Material Cost (per MT)</th>
<th>Capital Recovery</th>
<th>Overhead</th>
<th>Labour</th>
<th>Energy</th>
<th>Alumina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>$280.00</td>
<td>$135.00</td>
<td>$290.00</td>
<td>$395.00</td>
<td></td>
</tr>
<tr>
<td>Aluminium</td>
<td>$311.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Steel body cost @ $500/MT**
- Body complete weight: 435kg
- Total steel @ 50% M.U.: 870kg
- Total material cost: $435

**Steel body cost @ $750/MT**
- Body Complete weight: 435kg
- Total steel @ 50% M.U.: 870kg
- Total material cost: $652

**Aluminium body cost @ $1400/MT**
- Body complete weight: 260kg (-40%)
- Total aluminium @ 50% M.U.: 520kg
- Total material cost: $728

**Aluminium body cost @ $1200/MT**
- Body complete weight: 260kg (-40%)
- Total aluminium @ 50% M.U.: 520kg
- Total material cost: $624

Mark White, Automotive Aluminum Technology Forum, Detroit, 16 November 2004

Disruptive Technologies for Light Metals, April, 2006
Reduced Conversion Cost via Continuous Casting

Compared with conventional sheet processing
- No homogenisation
- No scalping
- Lower capital investment
- Faster processing
- Less energy, labour
- Equivalent properties

Cost of producing hot band AA5754 reduced
- 70 $/tonne cf 180 $/tonne (CRU)

Need a source of lower cost molten aluminium.
Cost Modelling of Aluminium Sheet Production

Conventional Auto-sheet route

Twin Roll Cast (TRC) Auto-sheet route

andy.darby@innovaltec.com

Disruptive Technologies for Light Metals, April, 2006
**DC & Continuous Belt Cast routes for AA5754 production**

- Capacity: 390 ktpa  Variable cost index: 1.6 (£59/tonne)
- Capacity: 110 ktpa  Variable cost index: 1.0 (£38/tonne)
- Capacity: 240 ktpa  Variable cost index: 1.0 (£37/tonne)

Sheet width: 1750 mm  Final Gauge: 1.2 mm  AA5754

Processing costs are relatively small compared to the metal cost and this is the major issue that needs to be addressed.
Relative cost of aluminium from individual smelters. Ranges from 900 to 2100 $/tonne
Aluminium from Cans to Cars

Can recycling at Novelis, Warrington

Cans are shredded to the size of 50p coins before being de-inked and melted

- 90,000 tonnes of cans into rolling ingots for more cans.
- But only 42% of beverage cans are recycled in Europe.
- In UK alone 45,000 tonnes of aluminium cans are land filled every year.
- Total European BIW structure market for aluminium is 34,000 tonnes.

Aluminium is cast into ingots, each large enough to make 1.5 million new cans
Environmental Benefits of Aluminium Recycling

- Remelting of recycled aluminium consumes only 5% of the energy required for primary production.
- Recycling is far less Greenhouse Gas intense.
- Alcoa utilises about 20% recycled metal for fabricated products.
- Alcoa is publicly committed to 50% of fabricated products from recycled metal by 2020.
Aluminium Sustainability

709 million MT produced

516 still in use

Global Metal Pool (Inventory)
- statistical totally available metal resources

Metal loss
- Destructive use (e.g. oxidation in steel industry)
- Natural oxidation (approx. 0.5 to 1%)
- Melt losses (thermal treatment of Aluminum)
- Metalworking (very small filings), Salt slag
- Economic losses (recycling 'presently' not economical)
- Historic losses (e.g. metall losses during wars)

Since 1888, 709 million metric tons of aluminum produced

75% of aluminium produced since 1888 is still in use
Automotive Sheet Recycling

Recycle
- Chemistry
- Scrap Value

Sheet Process
- Blending
- Chemistry Control
- Cold Rolling
- Annealing
- Finishing

Scrap
- Segregation
- Collection
- Handling
- Tier 2s

Blank
- Slitting
- Cut-to-length
- Laser Blanking

Stamping
- Stamping
- Trim

Additional Scrap
- Transport scrap
- Building scrap
- Can scrap

Coil

Additional Scrap
- Transport scrap
- Building scrap
- Can scrap

Disruptive Technologies for Light Metals, April, 2006
AA6011 Block cast from scrap: As Received 1.22 mm Acetone Degreased
0.41 Mn, 0.71 Fe, 0.8, Si, 1.16 Mg, 0.53 Cu, 0.057 Cr, 0.25 Zn, 0.046 Ti, 0.0011 Be, 0.021 Pb, 0.006 Sn, 0.0008 Na, 0.0011 Ca
Lockheed Filiform Test, NaOH/HNO₃ ~ 2 µm Removal, 1.22 mm Sheet (20 sec at 60°C)
Lockheed Filiform Test, NaOH/HNO₃ + Pyrosil Flame Spray,
### Chemical Composition of Cans

<table>
<thead>
<tr>
<th></th>
<th>Fe</th>
<th>Si</th>
<th>Mg</th>
<th>Mn</th>
<th>Cu</th>
</tr>
</thead>
<tbody>
<tr>
<td>AA3104 Can Body</td>
<td>0.4</td>
<td>0.2</td>
<td>1.2</td>
<td>0.9</td>
<td>0.2</td>
</tr>
<tr>
<td>AA5182 Can End &amp; Tab</td>
<td>0.2</td>
<td>0.1</td>
<td>4.7</td>
<td>0.3</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>Remelted UBC's</td>
<td>0.35</td>
<td>0.17</td>
<td>1.6</td>
<td>0.7</td>
<td>0.15</td>
</tr>
<tr>
<td>AA5754 Structural alloy</td>
<td>0.2</td>
<td>0.1</td>
<td>3.0</td>
<td>0.3</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>AA6016 skin alloy</td>
<td>0.2</td>
<td>1.2</td>
<td>0.5</td>
<td>&lt; 0.1</td>
<td>&lt; 0.1</td>
</tr>
<tr>
<td>AA6111 skin alloy</td>
<td>0.2</td>
<td>0.7</td>
<td>0.7</td>
<td>0.3</td>
<td>0.7</td>
</tr>
</tbody>
</table>

Recycled cans are an potential low cost source of automotive sheet. However present price paid for cans has risen to £950/tonne.
BCAST (Brunel University) has developed rheocasting technology capable of generating dramatic improvement in properties of casting alloys through microstructural refinement.
Rheocasting concepts for sheet products

DC Rheocasting process

Twin Roll RheoCasting
• Potential sheet price based on
  — Used Beverage Cans 2/3 price of LME metal (Foil scrap price around 2/5 LME).
  — Note: if all post consumer scrap was recycled, price likely to be even lower.

• Potential converting price based on continuous casting.

• Reduced alloying costs based on ability to generate improved properties through novel processing technology.

• Need to be able to convert to high quality automotive sheet without major use of high purity LME metal.
Challenges to the Aluminium Industry

- Under-exploited environmental benefits of aluminium exist in low CO$_2$ transportation.

- Adoption of aluminium sheet for mass production Aluminium Intensive Vehicles is limited by the present price of sheet.

- Sheet suppliers should do all in their power to remove unnecessary and sometimes costly processing steps.

- Major price reduction is possible if more post-consumer recycled aluminium was available, this needs to be diverted into automotive sheet from less environmentally beneficial applications.

- Strategic changes are required to enable automotive companies to realise the financial benefits of aluminium recycling enjoyed by users of other aluminium sheet products.