Forming Lightweight Materials for High Volume Production:

Aluminium Focus

Simon Black (Senior Manager - Body Structures, Jaguar Land Rover)
Global Automotive Lightweight Materials
25th April 2013
LWV Architecture Choice

Niche Volumes < 10,000 cars per year

Large Volumes > 50,000 cars per year

Cost structure needs to be adjusted for assembly

Structural die castings – saw tooth reflects replacement die cost

Extruded (& fabricated) components

Sheet stampings

Spaceframe of extrusions and nodes

Stampings intensive monocoque
JLR Aluminium BIW Heritage

Jaguar XK120 1948

Series 1 Land Rover 1948
3rd Generation “Light Weight Vehicle” Architecture

The 4th generation - the next chapter in the history of Range Rover
All-New Range Rover: Body less Doors

<table>
<thead>
<tr>
<th>Component Type</th>
<th>% Part No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stampings</td>
<td>88%</td>
</tr>
<tr>
<td>Castings</td>
<td>5%</td>
</tr>
<tr>
<td>Profiles</td>
<td>3%</td>
</tr>
<tr>
<td>Tubes</td>
<td>3%</td>
</tr>
<tr>
<td>Other</td>
<td>1%</td>
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</tbody>
</table>
All-New Range Rover: Material Technology

6000 alloys developed for improved strength & weight reduction

AC600T61 Crash Alloy development

One Piece Bodyside developed in AC170PX

Post Form Heat Treatment process (PFHT) 6111T4 alloy

High Pressure Die Castings used for part integration & stiffness

Aluminium Rolled Sections & Extruded Profile applications
All-New Range Rover: Material Breakdown

- **Al sheet 6xxx**: 37% by mass, 6xxx alloys, circa 10% increase in material cost, increased strength over 5xxx Alloys, cost saving/cost neutral.
- **Al sheet 5xxx**: 37% by mass.
- **Al casting**: 15% by mass.
- **Al extrusion**: 6% by mass.
- **HSS steel**: 1% by mass.
- **PHS steel**: 4% by mass.

6xxx alloys circa 10% increase in material cost
Increased strength over 5xxx Alloys
Cost saving / cost neutral
Anticorodal - AC300T61: Crash/Crush Alloy

In comparison to previous 5754 alloys:-
AC300T61 absorbs 30% more energy/unit length
Weight Saving 20% / part – over 6kg/vehicle
Piece Cost Saving circa 9% / part
Anticorodal®-300T61: Springback

The higher the Proof Stress, the higher the resulting Springback for the same gauge

Springback on simple flanges, in terms of "Degrees of Unbend" to go in proportion to the Proof Stresses

Expection that the over-bending required to overcome the springback to also be in proportion to the Proof Stresses
Anticorodal®-300T61: Mechanical Props

To understand relative formability of AC300T61

To provide the recognised strain Safety Limit (Necking Criteria) for use in
  > FE analysis
  > Circle Grid strain analysis following physical trials
Anticorodal®-300T61: Springback

A line-scan is taken along the centre line of each sample using a Optical Measurement System (GOM). An IGES file is constructed from these results and imported into a CAD package. Tangents 1 & 2 are constructed & angles A, C & E calculated.

Interchangeable tooling elements:
- Punch radius (12 mm)
- Die radius (8 or 12 mm)
- Drawbead depth (1 mm)
- Blankholder pressure (~10T)
- Draw depths (50 & 75 mm)

Angles of Interest:
- Angle "A": Side Wall Springback
- Angle "C": Side Wall curl
- Angle "E": Flange Springback

Ideal Part
Actual Part
Anticorodal®-300T61: Springback

U profile geometry requires the springback allowance to be increased from 4 NG 5754 (112 MPa) to 8 Ac300 T61 (205MPa)

Control Curl and Flange springback through minimizing draw depth
DVA Study conducted on Sled Runner.

The differences between each material are statistically negligible in terms of variation.

Decision to keep Matching Surface tolerance the same at NG5754

Zero impact on manufacturing Bill of Process (BoP)
**Anticorodal®-300T61: Formability**

<table>
<thead>
<tr>
<th></th>
<th>Ac300T61 (~180 MPa)</th>
<th>Ac300T61 (~240 MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Blank Edge Movement</strong></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>2. Forming Strain Analysis</strong></td>
<td>✓</td>
<td>(x)</td>
</tr>
<tr>
<td><strong>3. Thinning Strain Analysis</strong></td>
<td>✓</td>
<td>(x)</td>
</tr>
<tr>
<td><strong>4. Dimensional Measurement</strong></td>
<td>✓</td>
<td>x</td>
</tr>
<tr>
<td><strong>5. Cosmetic Evaluation</strong></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>6. Simulation Correlation</strong></td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

**10118**
X350 Front Sidemember
NG5754 2.0mm
Low complexity

| **243A18**
X350 B-pillar Reinforcement
6111T4 2.0mm
Medium complexity |
<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Blank Edge Movement</strong></td>
<td>?</td>
</tr>
<tr>
<td><strong>2. Forming Strain Analysis</strong></td>
<td>x</td>
</tr>
<tr>
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<tr>
<td><strong>6. Simulation Correlation</strong></td>
<td>?</td>
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**10776**
X350 Seat Cross member
NG5754 1.5mm
High complexity
One Piece Aluminium Bodyside: Background

X350 Jaguar XJ (previous model)
- 6 part bodyside assembly
- Main panel is 1.5mm NG5754

X351 Jaguar XJ (current model)
- 2 part bodyside assembly
- Main panel is 1.2mm 6111 T4
One Piece Aluminium Bodyside: Research

Correlation between off tool panel and Autoform simulation

Development Tool & Panel Tryout
One Piece Aluminium Bodyside: Summary

Designed to reduce total number of parts & joints
Weight Saving 2.8kg / vehicle
Piece Cost Saving circa £40 / vehicle
Investment Saving circa £2.5M / programme

Largest single aluminium body panel in the world

1.1mm AC170PX
Laser Cut Blank – 1.72m x 3.8m
Depth of draw over 300mm
5 operations per part
Tool size 5m x 2.5m x 1.5m
Post Form Heat Treated (PFHT) 6111 T4: Research

2009 - Initial lab scale development complete

2010 - External partners to full production readiness
  • Hurdles included
    > Robust Heat Treatment Cycle
    > Dimensional Stability
    > Joining

2012 – Automotive **World 1st** application of technology on **New Range Rover**
PFHT 6111T4: Process Verification

Production A and B Pillars

Utilized existing oven with modified rack

Tensile specimens extracted from 5 different locations and tested in three conditions:

- As-Formed, Paint Bake only and PFHT + Paint Bake

A statistical sample of parts were measured for strength, retained ductility and dimensional variation
**PFHT 6111T4: Process Verification**

<table>
<thead>
<tr>
<th></th>
<th>A-Pillar (Current Production)</th>
<th>A-Pillar (w/ PFHT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Panel Yield Strength, MPa</td>
<td>171</td>
<td>267</td>
</tr>
<tr>
<td>Gauge (mm)</td>
<td>2.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Blank Mass (kg)</td>
<td>2.11</td>
<td>1.35</td>
</tr>
<tr>
<td>Part Mass (kg)</td>
<td>0.64</td>
<td>0.41</td>
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</table>

<table>
<thead>
<tr>
<th></th>
<th>B-Pillar (Current Production)</th>
<th>B-Pillar (w/ PFHT)</th>
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</thead>
<tbody>
<tr>
<td>Minimum Panel Yield Strength, MPa</td>
<td>188</td>
<td>269</td>
</tr>
<tr>
<td>Gauge (mm)</td>
<td>2.0</td>
<td>1.4</td>
</tr>
<tr>
<td>Blank Mass (kg)</td>
<td>1.64</td>
<td>1.15</td>
</tr>
<tr>
<td>Part Mass (kg)</td>
<td>0.85</td>
<td>0.59</td>
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</table>
PFHT 6111T4: Summary

6111 T4 Material  
No Impact on Forming  
PFHT profile – 30 mins  
Good Joining Performance

6111 T6 = 8 hours at 180°C - limited formability & joining
PFHT 6111T4 circa 80 MPa increase in yield strength at 2% strain
Robust Heat Treatment Cycle & Dimensional Stability
Weight Saving circa 50% relative to comparable steel part
Piece Cost Saving circa £1.50 / part
All-New Range Rover: High Pressure Die Castings

HPD Castings:
14 Aluminium body structural castings
2 Magnesium castings
Local stiffness in high load areas
Complex geometry
Part integration
SPR & bonded
All-New Range Rover: Rolled Sections & Profiles

2 x Rolled Section Roof Bow
First application in JLR of aluminium rolled profiles
Low tooling investment cost
Potential for high strength aluminium alloy parts

9 x High strength alloy profiles
6182HS alloy used for extruded profiles,
Low tooling investment cost

4 x Tubular braces
Efficient method to achieve both local & global stiffness values
Jaguar XJ: Part Integration

- 1 piece door inner panel
- AA5182 alloy, 1.5mm gauge
- Weight and cost savings

<table>
<thead>
<tr>
<th></th>
<th>X350</th>
<th>New XJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Parts</td>
<td>14</td>
<td>10</td>
</tr>
<tr>
<td>Weight per car [Kg]</td>
<td>2.2</td>
<td>↓</td>
</tr>
<tr>
<td>Cost</td>
<td>10%</td>
<td>↓</td>
</tr>
</tbody>
</table>
The depth of draw and variable cross section across both front and rear door shutface surfaces eliminates the possibility to conventionally press this panel.

This depth of draw sets new industry standards for this complexity of panel form.
Sheet Metal Forming: Part Integration

Total hours per car to make an LWV has reduced by over 50%
Objective of the ReAlcar project:
- enable lightweight automotive body structures using aluminium sheet from low cost, energy efficient, recycled sources
- supports production of lower emission cars in direct response to governmental vehicle emission targets

Project is based on innovative recycled sheet aluminium developments through existing production processes at Novelis and continuous casting at Brunel University

Target is to deliver an affordable aluminium automotive sheet grade which supports lightweight vehicle structures with a low carbon footprint using sustainable resources and a recycled content of 75%
Thank You for Listening
Vielen Dank
Dhany Nad
Grazie
Merci