Hydroforming High and Ultra-High Strength Steel Tubular Automotive Parts

Blair Longhouse
VARI-FORM
High Strength Steel Challenges

• Fundamental challenge is lower formability
  • Less strain before fracture
  • Reduces achievable bending severity; angle, bend ratio
  • Expansion before and during hydroforming restricted
  • Punching Extruded Holes
  • Tool wear will increase; more when using higher pressure
  • Higher pressure needed to HPH expand

• Little effect on Pressure Sequence Hydroforming (PSH)
Simple Shape

More Complex Shape Pinching

Hydroforming Complex Shapes
Hydroforming HSLA Steel

310 MPa (45F) MYS HSLA Steel (unannealed)

<table>
<thead>
<tr>
<th>Material Type</th>
<th>YS MPa</th>
<th>UTS MPa</th>
<th>Elongation %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat Strip</td>
<td>372</td>
<td>452</td>
<td>31.0</td>
</tr>
<tr>
<td>Round Tube</td>
<td>407</td>
<td>465</td>
<td>30.0</td>
</tr>
<tr>
<td>Hydroformed</td>
<td>433</td>
<td>486</td>
<td>25.0</td>
</tr>
</tbody>
</table>

Material Sample
Taken from Crossbar

Ford Mondeo
Mystique/Contour Engine Cradle - 1992

310 MPa (45F) MYS HSLA Steel (unannealed)
### Forming UHSLA Steel

#### Table

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield Stress MPa</th>
<th>Ult. Stress MPa</th>
<th>Elong. %</th>
<th>Hole Position ($C_p$)</th>
<th>Internal Pressure Psi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild Steel</td>
<td>Tube</td>
<td>318</td>
<td>389</td>
<td>33</td>
<td>2.0</td>
</tr>
<tr>
<td></td>
<td>Formed</td>
<td>403</td>
<td>429</td>
<td>16</td>
<td>5,000</td>
</tr>
<tr>
<td>80Y-90T</td>
<td>Tube</td>
<td>600</td>
<td>706</td>
<td>17</td>
<td>2.6</td>
</tr>
<tr>
<td></td>
<td>Formed</td>
<td>610</td>
<td>727</td>
<td>11</td>
<td>5,000</td>
</tr>
</tbody>
</table>

- Samples formed in 1996 using the production Mild Steel Instrument Panel Beam Tooling
- Prototypes made with 552 MPa [80Y90T]
- Low elongation limits bending and Extruding
- Same Hydroforming Pressure
HSLA Steel Sample

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<th>Yield Stress MPa</th>
<th>Ult. Stress MPa</th>
<th>Elong. %</th>
</tr>
</thead>
<tbody>
<tr>
<td>UHSLA</td>
<td>580</td>
<td>641</td>
<td>17</td>
</tr>
</tbody>
</table>

1998
Thickness - 1.47 mm
Corner Radius - 3.0 mm (2t)
Forming Pressure - 7,000 psi
Dual Phase Steel

80Y 90T

- Formed in production tool
- Top part - 80Y 90T [552 MPa YS]
- Bottom part - 140Kpsi [966 MPa] min. UTS Steel
- Hole punching changes - development, limitations
- Potential applications: Bumper Beams, Roof Rails
Cross Section Changes
Without Expansion

Section height increased 60% vertically (top view)
### Different Wall Thicknesses

<table>
<thead>
<tr>
<th>Wall Thickness</th>
<th>Outside Corner Rad.</th>
<th>Steel Type</th>
<th>Maximum Pressure</th>
<th>Estimated Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 mm</td>
<td>9 mm (4.5T)</td>
<td>1010</td>
<td>5,600 psi</td>
<td>14,000 psi</td>
</tr>
<tr>
<td>3 mm</td>
<td>9 mm (3T)</td>
<td>1010</td>
<td>5,600 psi</td>
<td>25,000 psi</td>
</tr>
<tr>
<td>6.3 mm</td>
<td>9 mm (1.5T)</td>
<td>1026</td>
<td>6,000 psi</td>
<td>99,000 psi</td>
</tr>
</tbody>
</table>

Note: 6.3 mm material yield 50,000 psi (340 MPa)
Holes Punched In-Die

- Most Economical, Reduced Cycle Time
- Superior Location Repeatability
- High Hole Count (i.e. 64 - one die)
- Large Holes (i.e. 52 x 201 mm)
- Laser or Plasma cut not necessary

Any Shape | Pressure Pierce | Extruded

In die Slug Removal
RECIPE for LONG TERM SUCCESS

- Reduced COST
- Improved STRUCTURE
- Improved QUALITY
- Reduced MASS
Jeep Grand Cherokee
WG Roof Reinforcement

www.autosteel.org
Dodge Durango (2004)
Front End Structural Module [FESM]
Hydroforming Evolution
Flexible Body Architecture

2 Door → 4 Door

SUV

SUT

www.autosteel.org
Radiator Closure Design Optimization Study

Tools - Tailor welded tube, Tailor welded blanks, Mild Steel and AHSS
Hybrid front-end structure takes advantage of hydroformed metal tube and injection molded plastic.

Steel provides strength, stiffness, and the structural load path from the body to the chassis.

Plastic provides mounts for the hood latch, sensors, head lamps, radiator, grille & etc.
Summary

• New HSLA parts coming to market each year
• High strength steel provides better performance, lower cost & weight
• Bending limited as formability decreases; need to continue to improve formability
• Formed shape can be reasonably complex; no stretching
• HSLA, UHSLA, Dual Phase, and Trip Steels can be Pressure Sequence Hydroformed without extensive process development
• Advanced High Strength Steel can meet or exceed the performance of Light Alloy Materials

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