Hydroform Intensive Body Structure with Advanced High Strength Steels

Dean Gerlcke
Vari-Form
Agenda

1) Study Introduction – Assumptions
2) Front End Structure
3) Body Side Structure
4) Global NVH Performance
   5) Summary
6) Next Steps
Study Introduction - Assumptions

- Contracted EDAG to do the Engineering study utilizing a modified FSV (Future Steel Vehicle) structure.
- FSV is a 2025 m.y. “what if” vehicle utilizing extensive use of laser welded blanks and laser welded body.
- Baseline stamped vehicle wanted to be more like today’s BIW (conventional stampings and spot welded).
- Baseline stamped vehicle was also stretched (overhang and wheelbase), placing it size wise in the middle of C-segment vehicles.
- Baseline stamped vehicle materials are primarily AHSS (DP 800/1000).
Material Utilization

**Stamped**
(264.78 Kg)

- 45% < 500 MPa (UTS)
- 46% 500 – 1000 MPa
- 9% > 1000 MPa

**Hydroformed**
(250.15 Kg)

- 48% < 500 MPa (UTS)
- 46% 500 – 1000 MPa
- 6% > 1000 MPa
Material Utilization Comparison

Staked Baseline

Materials and Weights - Overview

75% < 500 MPa (UTS)
19% 500 - 1000 MPa
4% > 1000 MPa

Materials and Weights Overview

77% < 500 MPa (UTS)
17% 500 - 1000 MPa
4% > 1000 MPa
Front End Structure

**Stamped**
(50 Kg)

- 21% < 500 MPa (UTS)
- 79% 500 – 1000 MPa
- 0% > 1000 MPa

**Hydroformed**
(44.6 Kg)

- 19% < 500 MPa (UTS)
- 74% 500 – 1000 MPa
- 7% > 1000 MPa
Front End Structure

500 – 1000 MPa

FOV
Front End Structure

Hydroformed Components

4.00 in. dia. x .051 in.
DP 980 (x2/veh.)

2.50 in. dia. x .051 in.
DP 980 (x6/veh.)

500 - 1000 MPa

View A-A
Euro NCAP – Off-Set Barrier

Stamped

Hydroformed
Euro NCAP – Off-Set Barrier Intrusion

**Stamped**

**Hydroformed**
## Front End Performance Comparison

<table>
<thead>
<tr>
<th>Performance</th>
<th>Stamped</th>
<th>Hydroformed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Euro NCAP - Off Set Barrier (good rating)</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>US NCAP - Flat Frontal (&lt;40g)</td>
<td>39</td>
<td>39</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>49.95</td>
<td>44.63</td>
</tr>
<tr>
<td>Delta (Kg) [%]</td>
<td>-5.32 [-10.7%]</td>
<td></td>
</tr>
</tbody>
</table>
Front End Cost Comparison

EDAG Cost Model Used

**Cost**

- **Piece Cost**: 12% savings over stamped
- **Tooling**: 31% savings over stamped

* (includes component, sub-assy, and body shop assy. costs)
Body Side Structure

**Stamped**

(94.42 Kg)

- 39% < 500 MPa (UTS)
- 39% 500 – 1000 MPa
- 22% > 1000 MPa

**Hydroformed**

(89.32 Kg)

- 39% < 500 MPa (UTS)
- 50% 500 – 1000 MPa
- 11% > 1000 MPa
Hydroformed Components

2.75 in. dia. x 0.051 in.
DP 780 (x2/veh.)

2.25 in. dia. x 0.047 in.
DP 980 (x4/veh.)

500 – 1000 MPa
FMVSS 216A Roof Crush

Stamped

Hydroformed
FMVSS 216A Roof Crush Performance

Stamped

Hydroformed

Driver

Driver

Passenger

Passenger
IIHS Side Impact

Stamped

Hydroformed
IIHS Side Impact

- Stamped
- Hydroformed
## Body Side Performance

<table>
<thead>
<tr>
<th>Performance</th>
<th>Stamped</th>
<th>Hydroformed</th>
</tr>
</thead>
<tbody>
<tr>
<td>FMVSS 216 A Roof Crush (&gt;36.5 Kn both D&amp;P)</td>
<td>69D/68P</td>
<td>70D/73P</td>
</tr>
<tr>
<td>IIHS Side Impact (&gt;125 mm)</td>
<td>127</td>
<td>126</td>
</tr>
<tr>
<td>FMVSS 214 Pole Impact (&gt;125 mm)</td>
<td>133</td>
<td>142</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>94.42</td>
<td>89.32</td>
</tr>
<tr>
<td>Delta (Kg)%</td>
<td></td>
<td>-4.90 (6.0%)</td>
</tr>
</tbody>
</table>
Body Side Cost Comparison

EDAG Cost Model Used

Cost

<table>
<thead>
<tr>
<th>Description</th>
<th>Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piece Cost*</td>
<td>9% savings over stamped</td>
</tr>
<tr>
<td>Tooling*</td>
<td>7% savings over stamped</td>
</tr>
</tbody>
</table>

* [includes component, sub-assy, and body shop assy. costs]
Global NVH

Performance

**Bending (>40 Hz)**
- Stamped: 50.33
- Hydroformed: 46.44

**Torsion (>40 Hz)**
- Stamped: 44.20
- Hydroformed: 43.62

- target 3Hz separation between modes
Body Shop

Body Shop Floor Space
Hydroform saved 13859 sq. ft.
## Summary of Study

### Performance

- Matched/Exceeded Stamped – Impact/NVH

### Cost

- **($Cdn Savings)**
  - Piece Cost - $64.8 (-11%)
  - Tooling Cost - $11.2 mil. (-14%)

### Weight

- **(3 sub-systems)**
  - - 14.7 Kg (-7.3%)

### Assy. Plant Footprint

- - 13,859 sq. ft. (-7.5%)

### CO2

- - 487 Kg (life of vehicle) [-1%]
Next Steps

1) **Investigate Alternative Materials**
   - Boron
   - Aluminum
   - Stainless Steel

2) **Investigate Tailored Thickness Tubes**
   - tailor rolled tube
   - tailor welded tube (longitudinal/radial)

3) **Investigate Other Applications**

4) **Determine Assy Plant Process Limitations on Weight**
   (initiated)
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Hydroform Intensive Body Structure (HIBS) with Advanced and Ultra High Strength Steel Phase II

Dean Gericke
Vari-Form
1) HIBS I Recap

2) Study Introduction – Assumptions
   A) Front End Structure
      i) Mfg. Flexibility
      ii) Material Grade Change
      iii) Variable Gage Tubes
   B) Body Side Structure
   C) Rear End Structure

3) Summary
HIBS I – Recap

Cost

- Piece Cost: - 11% savings over stamped
- Tooling Cost: - 14% savings over stamped

Weight

- 14.7 Kg (7.3% savings over stamped)

(3 sub-systems)
Study Introduction – Assumptions

1) Utilize HIBS I hydroform as baseline for weight and performance comparisons

2) Assume performance neutral to HIBS I hydroform design

3) Three stages of change were investigated to understand weight and cost implications

4) Utilized the EDAG cost model in evaluating costs
1) Manufacturing Flexibility
   - one-sided weld in the body shop
   - remove hand off brackets

2) Material Grade Change
   - tubes from higher strength steel

3) Variable Wall Tube
   - tailor welded tubes
Front End Structure

View Looking Up From Bottom

HIBS I

HIBS II
1) Manufacturing Flexibility

Spot Welds

Section A-A

HIBS I

One-sided Welds

HIBS II
2) Material Grade Change

- No grade changes were made since DP980 was used for HIBS I
- Any further grade increase, brings questions about material elongation in impact
3) Tube Thickness Variation

Baseline gage of the tubes was 1.3 mm (HIBS I)
Front End Structure
## Front End Structure

<table>
<thead>
<tr>
<th>Structure</th>
<th>Weight (kg)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamped (Baseline)</td>
<td>50.0</td>
<td>185.00</td>
</tr>
<tr>
<td>HIBS I</td>
<td>44.6</td>
<td>163.27</td>
</tr>
<tr>
<td>HIBS II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfg. Flexibility</td>
<td>43.7 (-0.9)</td>
<td>155.92 (-7.35)</td>
</tr>
<tr>
<td>Material Change</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Variable Gage</td>
<td>43.0 (-1.6)</td>
<td>178.51 (+15.24)</td>
</tr>
</tbody>
</table>
Front End Structure

Cost vs. Mass
Parallels of constant value: US$ 9.00/kg

- HIBS II - Variable Gage
- HIBS I - Hydroform
- Stamped (Baseline)
- HIBS II - Mfg. Flexibility

Increasing value

Mass (kg)

Cost ($)
Body Side Structure

HIBS I

HIBS II
1) Design Changes

HIBS I

HIBS II

Section B-B
1) Design Changes

HIBS I

HIBS II
2) Material Grade Change

- DP 780
- DP 980
- HIBS I
- HIBS II
- 1300 Mpa Material
3) Variable Gage

- $t = 0.70 \text{ mm}$
- $t = 0.75/0.80 \text{ mm}$
- $t = 0.90 \text{ mm}$
Body Side Structure

HIBS I

HIBS II

Platen Force vs. Displacement Driver Side

<table>
<thead>
<tr>
<th>Force lbf</th>
<th>Displacement (in)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2500</td>
<td>1</td>
</tr>
<tr>
<td>5000</td>
<td>2</td>
</tr>
<tr>
<td>7500</td>
<td>3</td>
</tr>
<tr>
<td>10000</td>
<td>4</td>
</tr>
<tr>
<td>12500</td>
<td>5</td>
</tr>
<tr>
<td>15000</td>
<td>6</td>
</tr>
</tbody>
</table>

[Graph showing force vs. displacement for HIBS I and HIBS II]
## Body Side Structure

<table>
<thead>
<tr>
<th>Structure</th>
<th>Weight (kg)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stamped</strong> (Baseline)</td>
<td>94.4</td>
<td>265.64</td>
</tr>
<tr>
<td><strong>HIBS I</strong></td>
<td>89.3</td>
<td>241.12</td>
</tr>
<tr>
<td><strong>HIBS II</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfg. Flexibility</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Material Change</td>
<td>86.2 (-3.1)</td>
<td>275.23 (+34.11)</td>
</tr>
<tr>
<td>Variable Gage</td>
<td>83.9 (-5.4)</td>
<td>301.69 (+60.57)</td>
</tr>
</tbody>
</table>
Cost vs. Mass
Parallels of constant value: US$ 9.00/kg

- HIBS II - Variable Gage
- HIBS II - Material Change
- HIBS I - Hydroform
- Stamped (Baseline)

Mass (kg)
0
220
240
260
280
300
320

Cost ($)
Rear Floor Structure

HIBS I

Section C-C

HIBS II
Rear Floor Structure

Rear Bumper Profile

Distance from vehicle centerline (mm)
+y direction from driver to passenger side

HIBS 1
HIBS 2
## Rear Floor Structure

<table>
<thead>
<tr>
<th>Structure</th>
<th>Weight (kg)</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stamped (Baseline)</td>
<td>57.3</td>
<td>175.96</td>
</tr>
<tr>
<td>HIBS I</td>
<td>53.1</td>
<td>157.62</td>
</tr>
<tr>
<td>HIBS II</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mfg. Flexibility</td>
<td>50.6 (-2.5)</td>
<td>150.69 (-6.93)</td>
</tr>
<tr>
<td>Material Change</td>
<td>49.8 (-3.3)</td>
<td>150.16 (-7.46)</td>
</tr>
<tr>
<td>Variable Gage</td>
<td>49.4 (-3.7)</td>
<td>158.26 (+0.64)</td>
</tr>
</tbody>
</table>
Rear Floor Structure

Cost vs. Mass
Parallels of constant value: US$ 9.00/kg

Cost ($)

$200
$190
$180
$170
$160
$150
$140

Mass (kg)

48.0
50.0
52.0
54.0
56.0
58.0
60.0

Increasing value

Stamped (Baseline)

HIBS II - Variable Gage
HIBS II - Material Change
HIBS II - Mfg. Flexibility
HIBS I - Hydroform
Summary

1) Once hydroforming is implemented, the most significant weight and cost reduction will be realized (HIBS I)

2) Further hydroforming weight and cost reduction opportunities exists (HIBS II)

3) One-sided welding is a significant enabler for future cost and weight reduction
Thank You