Design & Manufacturing a DP980 B-Pillar Inner for the GM Chevy Equinox / Pontiac Torrent

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Gopal Nadkarni, Mittal Steel USA
OUTLINE

- Design for Roof and Front Offset Crash
  - Design with AHSS Solutions
  - Design for Formability
- Production Experiences DP980 B-Pillar
  - Manufacturing Considerations
  - Process Selection & Tool Development
  - Lessons Learned
  - Summary
Why have we changed the current design?

Increasing Government Regulation and Customer Demand for Safety

Roof crush requirements

<table>
<thead>
<tr>
<th>Up to 2010</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5x</td>
<td>2.5x</td>
</tr>
</tbody>
</table>

X = vehicle curb mass

Front crush

Front offset crush

NEW
Front Offset and Roof Crush Contributors

Roof Rail
HSLA 340, 1.5 mm

A-Pillar
HSLA 340, 2.0 mm

Body Side Outer
HSLA 340, 1.4 mm

B-Pillar
HSLA 340, 1.2 mm

**DESIGN DIRECTION**

<table>
<thead>
<tr>
<th></th>
<th>ADDING CONVENTIONAL HSLA REINFORCEMENTS</th>
<th>USING AHSS / DUAL PHASE STEEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Risk : Less formability issues likely</td>
<td>High Risk: More steel formability issues likely</td>
<td></td>
</tr>
<tr>
<td>Added mass: ~ 30 Kg/vehicle</td>
<td>Added mass: ~ 0.6 Kg/vehicle</td>
<td></td>
</tr>
<tr>
<td>Added cost: ~ $ 60/vehicle</td>
<td>Added cost: ~ $ 4/vehicle</td>
<td></td>
</tr>
<tr>
<td>Assembly: Restricted</td>
<td>Assembly: Not Affected</td>
<td></td>
</tr>
<tr>
<td>Packaging: Environment not changeable</td>
<td>Packaging: Not Affected</td>
<td></td>
</tr>
</tbody>
</table>
AHSS Material Alternatives

- **DP980**
  - YS > 550 MPa
  - TS > 980 MPa
  - TE > 8%

- **DP780**
  - YS > 420 MPa
  - TS > 780 MPa
  - TE > 15%

- **DP690**
  - YS > 550 MPa
  - TS > 690 MPa
  - TE > 15%

- **DP590**
  - YS > 340 MPa
  - TS > 590 MPa
  - TE > 21%

- **HSLA340**
  - YS > 340 MPa
  - TS > 410 MPa
  - TE > 21%

- **Mild**
  - YS = 180 MPa
  - TS = 310 MPa
  - TE = 45%

- **Engineering Strain**

- **Engineering Stress (MPa)**

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**ROOF AND FRONTAL OFFSET CRUSH PACKAGE**
Perform design iterations by modifying the material type and thickness as well as studying possible shape changes to increase structural strength and formability requirements.

### MAIN CONTRIBUTORS

<table>
<thead>
<tr>
<th></th>
<th>ROOF CRUSH</th>
<th>FRONT OFFSET CRUSH</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROOF CRUSH PASS</td>
<td>FODB PASS</td>
<td></td>
</tr>
<tr>
<td>ROOF CRUSH FAIL</td>
<td>FODB FAIL</td>
<td></td>
</tr>
</tbody>
</table>

**Roof Rail**
- CR DP 690, 1.2 mm
- CR DP 780, 1.5 mm
- CR DP 980, 2.0 mm

**A-Pillar**
- CR DP 680, 1.2 mm
- CR DP 780, 1.5 mm
- CR DP 980, 2.0 mm

**B-Pillar**
- CR DP 690, 1.2 mm
- CR DP 780, 1.5 mm
- CR DP 980, 2.0 mm

**Body Side Outer**
- HSLA 340, 1.2 mm
- HSLA 380, 1.5 mm
- HSLA 410, 2.0 mm
Design Iterations using AHSS

ROOF AND FRONTAL OFFSET CRUSH PACKAGE

Design iterations

Current | DP 690 | DP 780 | DP 980
---|---|---|---
1.2mm | 1.5mm | 1.5mm | 1.2mm
2.0mm | 2.0mm | 2.0mm |
1.5mm | 1.5mm | 1.5mm |
1.2mm | 1.2mm | 1.2mm |

DP980, 1.5 mm thick
ROOF AND FRONTAL OFFSET CRUSH PACKAGE

Design for Formability

From the current part … … to final product

Improve section stiffness

Material Data
Formability Studies
Prototype learning
Dies Try Out

INPUTS

Avoid cracks
Control spring back
Typical Properties

YS, MPa : 650
TS, MPa : 1025
TE, % : 13

**Microstructure**

- DP980
  - Ferrite
  - Martensite

**Circle Grid Analysis**

- Wrinkling
- Splitting

Formed at reduced bead force. Splitting location is beyond trim line but there is increased risk of wrinkling compared to the result of DP690.

**Forming Limit Diagram**
ROOF AND FRONTAL OFFSET CRUSH PACKAGE

Design for Formability and Strength

Current part

Redesigned part

Geometry changed to:
1. Avoid splits along the vertical edges
2. Control the spring back of the ‘U’ channel
3. Strengthen the top portion where the failure happen

www.autosteel.org
Added vertical beads to control the spring back of the ‘U’ channel and for dimensional control.

Profile without beads

Profile with beads

Past design

New design
ROOF AND FRONTAL OFFSET CRUSHPACKAGE

Springback Control

25 mm

Die profile

B-Pillar profile

B-Pillar profile

Die profile
Production Experience
B-Pillar Inner DP980

Matt Rodzik, NARMCO
With over 60 years of stamping experience

Specializing in Deep draw, HSLA and AHSS

**SIGNIFICANT FIRST**

Production of DP 980 B-Pillar Inner

**B-PILLAR INNER (year 2006)**
Material: DP 980T/550Y t=1.5mm

**COMPRESSION PLATE (year 2000)**
Material: (DP 600) t=1.4mm

**ROCKER REINF. (year 2003)**
Material: t=1.65mm (DP600)
MANUFACTURING and TOOLING DESIGN CONSIDERATIONS

MANUFACTURING
- PRESS FORCES
- DIMENSIONAL STABILITY
- TOOL ROBUSTNESS
- MATERIAL VARIABILITY
- MAINTENANCE

TOOLING DESIGN
- SPRINGBACK AND DIMENSIONAL CONTROL
  - Sidewall Curl
  - Twist
  - Angular Springback
- TRIM EDGE
  - Trim Clearance
  - Trim Angle
  - Tool Geometry
- TOOL MATERIAL SELECTION
  - Impact
  - Wear

Final Selection Of The Process Is Dependent On Above Factors
PROCESS DESIGN CONSIDERATION

PROCESS SIMULATION

DRAW DIE
• More Splitting & Thinning
• More Side Wall Curl
• Less Wrinkling
• More Work Hardening
• Material Wastage

CRASH FORM DIE
• Eliminate Splitting
• Less Side Wall Curl
• More Wrinkling
• Less Work Hardening
• Less Material
MANUFACTURING PROCESS

FORM DIE → TRIM DIE → RESTRIKE DIE → PIERCE DIE
TOOL DEVELOPMENT with AHSS

DESIGN INFLUENCES

- **OPTIMAL RADIUS?**
  - $R/t > 2.5t$

- **HOW MANY SIDE WALL BEADS AND SHAPE?**
  - Dimensional Stability
  - Adjustability

- **OPTIMAL WALL ANGLE?**
  - > 8’ - 15’ for overbending

- **OPTIMAL EDGE CONDITION?**
  - Trim Angle & Clearance

- **OPTIMAL SIDE WALL CLEARANCE?**
  - 1xt (NO CLEARANCE)

*All form to be completed in first operation*
OVERBEND

- Form Die
  - 8’ Overbend Wall (Max)
- Restrike Die
  - 8’ Overbend Wall
  - 15’ Overbend Flange
  - Increase Form Depth
TOOL CONSTRUCTION

– D2 Coated Inserts Upper Cavity
– 4140 Post

LESSONS LEARNED

– Hardened inserts with coating to reduce wear and scoring
– Stripper Force – Additional Knockouts
– Draft Angle for Springback
TOOL CONSTRUCTION

- M4 Powder Metal Coated Inserts in Upper Cavity
- 4140 Post

LESSONS LEARNED

- Coin Radius after Flanging to set geometry
- Pad Pressures Increased (2x 35ksi to 65 ksi)
- Post Stretch to net shape
- Hardened inserts with coating
- Adjustable Stiffening darts
TOOL CONSTRUCTION
- D2 cutting Steel
- CPM 3V & S7 Inserts

LESSONS LEARNED
- Shear 2-4x thickness (12”section)
- Trim Angles 10° -15° max
- Key all sections for thrust
- Trim Clearance 10% -12%
- Increase clearance to improve tool life and reverse burrs
- No Edge Splitting
- The hardness of the incoming steel for draw is HV307 (~ Rc 30)
- The hardness of the steel in the bead area after forming is HRV 320-350 (~ Rc 34)
- Selection of appropriate coating is critical and needs further optimization

<table>
<thead>
<tr>
<th>Tool Insert</th>
<th>Form</th>
<th>Restrike</th>
<th>Trim</th>
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<tbody>
<tr>
<td>A2</td>
<td></td>
<td></td>
<td>Poor</td>
</tr>
<tr>
<td>CPM 3V</td>
<td></td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>S7</td>
<td></td>
<td></td>
<td>Good</td>
</tr>
<tr>
<td>D2</td>
<td>Poor (100pcs)</td>
<td>Poor (&lt; 1,000)</td>
<td>Fair</td>
</tr>
<tr>
<td>D2 + TIC</td>
<td>Good (&gt;TBD)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>D2 + TD</td>
<td>Good (&gt;40,000)</td>
<td>Poor (&lt; 2,400)</td>
<td>-</td>
</tr>
<tr>
<td>M4</td>
<td></td>
<td></td>
<td>Fair</td>
</tr>
<tr>
<td>M4 + TIC</td>
<td></td>
<td>Good (&gt;10,000)</td>
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<td>Poor (&lt; 2,400)</td>
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M4 Insert
Coated w/ TiC
PRODUCTION EXPERIENCE SUMMARY

PRODUCT DESIGN & PROCESS SELECTION

- A Product That Can Be Processed In One Operation
- Good Product & Tooling Design Can Manage Springback And Wall Curl

COST

- Premium Die Grade With *Conventional Processes*
  - Use Hardened and Coated Inserts For Adjustability And Wear
- Longer Development Time

TECHNICAL SUPPORT

- Steel Supplier, Tooling Supplier and Product Designer
DP980 CAN BE USED FOR STAMPING B-PILLAR INNER REINFORCEMENTS!!!

An Economical and Manufacturable Product To Meet Future Needs

QUESTIONS?