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ArcelorMittal Dofasco, ArcelorMittal USA, Nucor Corporation, Severstal North America, Inc. and United States Steel Corporation
Future Generation Passenger Compartment - Validation

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General Motors Corporation
Auto/Steel Partnership Members

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Mike Bzdok (A/SP)
• Project Description
  • Problem & Benefits
  • Scope
  • Process
• Project Results
  • Design changes
  • Performance results vs. baseline
  • Mass reduction
Vehicle mass reduction is increasingly important for future vehicle designs, however body structure mass has been increasing due to increases in performance requirements.
• Primary focus is mass reduction
• Match baseline performance in all other criteria
  — Dynamic and Static Stiffness
  — Crash Test Performance
  — Durability
PROJECT DESCRIPTION

• Optimize:
  — Geometry: optimize load path and shape
  — Grade: optimize with higher grades where needed
  — Gauge: down-gauge where possible

• Analyze:
  — CAE: Use modeling to predict level of performance and compare to criteria

• Validate:
  — Analysis as confirmation
PROJECT DELIVERABLES

• Mass Reduction: Target 30% of passenger compartment
• Static & Dynamic Stiffness: Meet or slightly exceed baseline
• Side Impact Performance: Maintain crash rating of baseline (structural criteria only)
• Roof Strength: Meet baseline target
• Offset Deformable Barrier
• Other Crash Tests: Confirmation checks on other crash test performance levels such as NCAP, Rear Impact, Seat Belt Pull to ensure no degradation.
FGPC Baseline Structure
- Passenger Compartment shaded in red
- Remaining structure in gray
Simultaneous optimization of Geometry, Grade and Gauge to reduce mass

- Applied optimization techniques to determine optimal locations for structural load paths and section shapes (geometry optimization)

- Choice of material grade and gauge optimized for the new geometry

- Additionally, considered effect of continuous joining
PROJECT RESULTS

• Design changes
  • Added Two Load paths
  • Many grade increases
  • Many gauge decreases
• Performance results vs. baseline
  • Structural criteria met
  • Variation with seat location
  • Further improvement with continuous joining
• Mass reduction between 15-20%
Load Path Optimization resulted in addition of two new load paths

- Cross car lower load path at base of B-pillar
- Roof Bow slightly rearward of upper B-pillar
B-PILLAR LOAD PATH DETAILS

Interface between Seat and Center Console

Interface between Seat and B-Pillar
New or no change
Higher grade over baseline
Lower grade over baseline
## PERFORMANCE SUMMARY

New Design Met the following load cases:

<table>
<thead>
<tr>
<th>LOADCASE</th>
<th>TARGET</th>
<th>FINAL DESIGN</th>
<th>MET TARGET?</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIHS Side Impact</td>
<td>Survival Space</td>
<td>83mm</td>
<td>109mm</td>
</tr>
<tr>
<td>FMVSS 216 Roof Crush</td>
<td>Crush Force</td>
<td>2.75 x Curb Weight (48.5kN)</td>
<td>2.76 x Curb Weight (48.7kN)</td>
</tr>
<tr>
<td>FMVSS 214 Door Intrusion</td>
<td>Front Door 6”</td>
<td>2250lbf</td>
<td>3529lbf</td>
</tr>
<tr>
<td></td>
<td>12”</td>
<td>3500lbf</td>
<td>6558lbf</td>
</tr>
<tr>
<td></td>
<td>Rear Door 6”</td>
<td>2250lbf</td>
<td>4435lbf</td>
</tr>
<tr>
<td></td>
<td>12”</td>
<td>3500lbf</td>
<td>7992lbf</td>
</tr>
<tr>
<td>IIHS Front Crash 40% ODB</td>
<td>Footwell</td>
<td>150mm</td>
<td>54mm</td>
</tr>
<tr>
<td></td>
<td>Left Toe Pan</td>
<td>150mm</td>
<td>73.8mm</td>
</tr>
<tr>
<td></td>
<td>Center Toe Pan</td>
<td>150mm</td>
<td>99.4mm</td>
</tr>
<tr>
<td></td>
<td>Right Toe Pan</td>
<td>150mm</td>
<td>70.7mm</td>
</tr>
<tr>
<td></td>
<td>Brake Pedal</td>
<td>50mm</td>
<td>111.3mm</td>
</tr>
<tr>
<td></td>
<td>Left IP</td>
<td>50mm</td>
<td>39.5mm</td>
</tr>
<tr>
<td></td>
<td>Right IP</td>
<td>50mm</td>
<td>30.6mm</td>
</tr>
<tr>
<td>NPRM FMVSS 214 Pole Impact</td>
<td>Survival Space</td>
<td>83mm</td>
<td>99.7mm</td>
</tr>
<tr>
<td>Modal &amp; Static Stiffness</td>
<td>Static Torsion</td>
<td>23.594 Nm/deg</td>
<td>24.309 Nm/deg</td>
</tr>
<tr>
<td></td>
<td>Static Bending</td>
<td>9.078 N/mm</td>
<td>9.080 N/mm</td>
</tr>
<tr>
<td></td>
<td>Torsional Mode</td>
<td>45.8 Hz</td>
<td>55 Hz</td>
</tr>
<tr>
<td></td>
<td>Bending Mode</td>
<td>46.5 Hz</td>
<td>46 Hz</td>
</tr>
<tr>
<td>NCAP Front Crash</td>
<td>Time to Zero Velocity</td>
<td>72msec</td>
<td>71msec</td>
</tr>
<tr>
<td></td>
<td>Max Crush Dist</td>
<td>680mm</td>
<td>673mm</td>
</tr>
<tr>
<td>FMVSS 301 Rear Crash</td>
<td>Maintain performance of Donor Vehicle</td>
<td>Achieved</td>
<td>YES</td>
</tr>
<tr>
<td>FMVSS 207/210 Seatbelt Pull</td>
<td>Maintain performance of Donor Vehicle</td>
<td>Achieved</td>
<td>YES</td>
</tr>
<tr>
<td>Durability</td>
<td>Maintain performance of Donor Vehicle</td>
<td>YES</td>
<td></td>
</tr>
<tr>
<td>Formability</td>
<td>Modified parts to pass one-step formability</td>
<td>Achieved</td>
<td>YES</td>
</tr>
</tbody>
</table>

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Auto/Steel Partnership
# SEAT POSITION SENSITIVITY

New design exceeded target of 83mm for IIHS Side Impact

## Table: IIHS Side Impact Results

<table>
<thead>
<tr>
<th>Driver’s Seat Position</th>
<th>Load case</th>
<th>Passenger’s Seat Position</th>
<th>IIHS Side Impact Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forward/High</td>
<td>1</td>
<td>Forward/High</td>
<td>116 mm</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Rearward/Low</td>
<td>101 mm</td>
</tr>
<tr>
<td>Rearward/Low</td>
<td>3</td>
<td>Forward/High</td>
<td>98 mm</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>Rearward/Low</td>
<td>99 mm</td>
</tr>
<tr>
<td>Opt Position (5&lt;sup&gt;th&lt;/sup&gt; Percentile)</td>
<td>Opt Position (5&lt;sup&gt;th&lt;/sup&gt; Percentile)</td>
<td>115mm</td>
<td></td>
</tr>
</tbody>
</table>
Added adhesive in all joints to assess maximum potential

Total Adhesive Mass ~ 1.1kg
CONTINUOUS JOINING RESULTS

Assessed performance improvements for adhesive (Spot-weld w/ bond) and laser welding
• Adhesive yielded the highest gains
• Performed gauge optimization to assess potential mass savings with comparable performance

<table>
<thead>
<tr>
<th></th>
<th>PERFORMANCE IMPROVEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SPOT-WELD→LASER</td>
</tr>
<tr>
<td>IIHS Side Impact</td>
<td>2%</td>
</tr>
<tr>
<td>IIHS Front Impact ODB</td>
<td>16% to 44%</td>
</tr>
<tr>
<td>Roof Crush</td>
<td>15%</td>
</tr>
<tr>
<td>Bending</td>
<td>13%</td>
</tr>
<tr>
<td>Torsion</td>
<td>14%</td>
</tr>
</tbody>
</table>
Load path combined with grade and gauge optimization yielded mass savings of 15%.

Seat load path sensitivity to seat location appears manageable.

Extensive application of adhesive shows promise, but further study required to determine optimal adhesive patterns / business trade offs required.

Expansion of analysis beyond passenger compartment may yield further mass savings.
Questions?
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