EFFICIENT STEEL BUMPER BEAM DESIGN

STEEL BUMPER SYSTEMS FOR PASSENGER CARS AND LIGHT TRUCKS - 7TH EDITION

AISI Automotive Webinar
JUNE 25, 2020
EFFICIENT STEEL BUMPER BEAM DESIGN

Introduction: John Catterall
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American Iron and Steel Institute
EFFICIENT STEEL BUMPER BEAM DESIGN

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Technical Consultant, Bumper Systems - AISI Bumper Team
Former System Architect, Bumper Systems – General Motors Company
Efficient Steel Bumper Beam Design

Agenda

1. Automotive Bumper Systems – General Status
2. Bumper System Performance Trends
   - Low Speed
   - High Speed
3. New Requirements affecting Bumper Beam Material
4. Benchmarking Study – Beam Material
Efficient Steel Bumper Beam Design

Agenda - continued

5. Case Study – Front Mid-size Car Bumper Beam
6. Conclusions
1. Automotive Bumper Systems – General Status

• Have become integral to Vehicle Styling.
• Carrying more diverse components.
• Increasingly diverse functionality
• Must maintain High and Low Speed Requirements
2. Bumper System Performance Trends

Decreased focus on Low Speed Bumper Performance

- US & EU Bumper Regulations remained unchanged for many years.
- EU & Korea Low Speed performance driven by Insurance testing.
- US - decreased focus on Low Speed Impacts caused by 2 factors:
  1. Market Change from Passenger Cars to SUV and Light Trucks.
  2. IIHS stopped testing Low Speed Bumper Performance.

Manufacturers are not placing a high priority on low speed bumper performance in most regions.
2. **Bumper Requirements Trends**

Increased focus on High Speed Crash Performance

- Higher requirements on Vehicle Occupant Protection
- Increased challenges of Battery Electric Vehicles:
  - Requirement to protect the battery like a fuel tank.
  - Increased size of battery in comparison to a fuel tank.
  - Increased vehicle mass.
  - Tougher to meet FMVSS 301 Fuel Tank Test – Rear – 70% overlap
2. Bumper Requirements Trends

Increased focus on High Speed Crash Performance – continued.

- Increased number of impact locations at higher speeds
  - IIHS Small Overlap Frontal Test – Front – 25% overlap – Driver & Passenger
  - EuroNCAP Mobile Progressive Deformable Barrier Test – Front – 50% overlap

Increased high speed crash performance is driving new requirements into the bumper beam.
3. New Requirements Affecting Beam Material

• Continued need for lightweight design.

• Performance Requirements:
  o Beam is first structural component to manage energy in a crash.
  o Beam must work integrally with vehicle structure in crash events.
  o High Speed Crash Requirements will drive stronger and tougher Bumper Beams to fully engage vehicle structure.

• Ultra High Strength Steel is 4 to 6 times stronger than aluminum.

Important to keep steel under consideration when designing a lightweight bumper.
3. New Requirements Affecting Beam Material

At lower strengths, Aluminum Bumper Beams will be:

- Lower Mass
- Cost Efficient
  - Low $/kg mass savings.
3. New Requirements Affect on Beam Material

As strength requirements increase, material selection will depend on a high cost per unit mass saved.

<table>
<thead>
<tr>
<th>Material</th>
<th>Increase Mass</th>
<th>Increase Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>?</td>
<td>Steel</td>
</tr>
</tbody>
</table>

Increase Mass

As strength requirements increase, material selection will depend on a high cost per unit mass saved.
3. New Requirements Affect on Beam Material

As strength requirements increase, steel Bumper Beams will be:

- Lighter than Aluminum
- Lower Cost than Aluminum

Efficient steel designs can deliver the increased strength needed for vehicle high speed crash at lower cost & mass.
4. Benchmarking Study – Beam Material

• Study of Bumper Beams on Mid-sized cars (C segment)
• A2Mac1 Data – all global regions for 2015-18 – approx. 140 vehicles

Steel is the material of choice for bumpers – approx. 70% market
4. Benchmarking – Beam Material – Midsize Cars

- All Front Beams are metallic material - reason - tougher frontal crash requirements.
- Rear Beams will have higher strength requirements to protect the battery pack in Electric Vehicles.

Use of Steel will likely increase to meet tougher high speed requirements.
5. Case Study – Front Mid-size Bumper Beam

• Comparison of Engineered Cost and Mass of:
  1. Extruded Aluminum – Production Part
  2. Hot Form Steel Design – optimized by computer FEA.
  3. Roll Form Steel Design – optimized by computer FEA.
5. Case Study – Front Mid-size Bumper Beam

• Requirements
  1. RCAR Bumper Test – 100% overlap @ 10 kph
  2. IIHS Small Overlap Frontal – 25% overlap @ 64 kph

RCAR Bumper Test

IIHS Small Overlap Test
5. Case Study – Front Mid-size Bumper Beam

#1. Extruded Aluminum – Assembly mass: 7.2 kg.
   - Extruded Bar – bent in plan view
   - Welded Brackets – extruded & stamped

Crush cans & Brackets for IIHS SOF Test

Center Reinforcement for RCAR Override Test
5. Case Study – Front Mid-size Bumper Beam

#2. Hot Form Steel - Assembly Mass: 9.5 kg
- 2 Piece Beam – welded together on top and bottom
- Welded stamped Brackets – Center & Mounting

Center Reinforcement for RCAR Override Test

Crush cans & Brackets for IIHS SOF Test
5. Case Study – Front Mid-size Bumper Beam

#3. Steel Roll Form - Assembly Mass: 9.4 kg
  o Roll Formed Beam – plan view sweep
  o Welded stamped Brackets – Center & Mounting

Crush cans & Brackets for IIHS SOF Test

Center Reinforcement for RCAR Override Test
5. Case Study – Front Mid-size Bumper Beam

• Engineered Cost Comparison

<table>
<thead>
<tr>
<th></th>
<th>Asm. Mass (kg)</th>
<th>Engineered Cost (US $)</th>
<th>Cost/kg for Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Aluminum</td>
<td>7.2</td>
<td>$60.30</td>
<td></td>
</tr>
<tr>
<td>#2 Steel Hot Form</td>
<td>9.5</td>
<td>$51.20</td>
<td></td>
</tr>
<tr>
<td>#3 Steel Roll Form</td>
<td>9.4</td>
<td>$42.08</td>
<td></td>
</tr>
</tbody>
</table>

Steel offers options to significantly reduce vehicle cost.
5. Case Study – Front Mid-size Bumper Beam

Assembly Breakdown:

1. Bumper Beam
2. Crush Cans - design dependent on vehicle crash strategy.
3. Center Reinforcement – only needed for RCAR Bumper Test

Focus on the Bumper Beam
### 5. Case Study – Front Mid-size Bumper Beam

<table>
<thead>
<tr>
<th>Mass Breakdown</th>
<th>Asm (kg)</th>
<th>Beam (kg)</th>
<th>Crush Can (kg)</th>
<th>Ctr. Reinf. (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Aluminum</td>
<td>7.2</td>
<td>4.0 (55%)</td>
<td>3.2 (42%)</td>
<td>0.2 (3%)</td>
</tr>
<tr>
<td>#2 Steel Hot Form</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>#3 Steel Roll Form</td>
<td></td>
<td></td>
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</table>

**Note:**
1. Aluminum Beam is a higher % of the assembly mass.
5. Case Study – Front Mid-size Bumper Beam

• Beam Mass Comparison

<table>
<thead>
<tr>
<th></th>
<th>Beam Mass (kg)</th>
<th>Difference (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Aluminum</td>
<td>4.0</td>
<td></td>
</tr>
<tr>
<td>#2 Steel Hot Form</td>
<td>4.3</td>
<td>+0.3</td>
</tr>
<tr>
<td>#3 Steel Roll Form</td>
<td>4.2</td>
<td>+0.2</td>
</tr>
</tbody>
</table>

Goal: Reduce the mass of Steel Beams
5. Case Study – Front Mid-size Bumper Beam

• Roll Formed Steel Beam – Mass Reduction

Case Study

Proposal

10% reduction in Beam mass
5. Case Study – Front Mid-size Bumper Beam

- Proposed Section Mass Comparison – 10% reduction

<table>
<thead>
<tr>
<th></th>
<th>Beam Mass (kg)</th>
<th>Reduce Beam by 10% (kg)</th>
<th>Diff (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1 Aluminum</td>
<td>4.0</td>
<td>Base</td>
<td></td>
</tr>
<tr>
<td>#2 Steel Hot Form</td>
<td>4.3</td>
<td>3.9</td>
<td>-0.4</td>
</tr>
<tr>
<td>#3 Steel Roll Form</td>
<td>4.2</td>
<td>3.8</td>
<td>-0.4</td>
</tr>
</tbody>
</table>

Steel has technology to save mass over Al on Beams
6. Conclusions

• Increasing High Speed Crash requirements create a need for higher strength Bumper Beams.

• Higher mass Battery Electric Vehicles are creating additional performance requirements for bumper beams in high speed crash.

• Ultra-high strength steel enables stronger Bumper Beams at lower mass and lower cost.

- An in-depth report on steel bumper systems including information on:
  - Material Properties
  - Manufacturing
  - Product Design
- Co-Authors: Hesham Ezzat and Stu Brown
- Project Manager: Michael White
- [https://www.steel.org/steel-markets/automotive/bumpers](https://www.steel.org/steel-markets/automotive/bumpers)
Efficient Steel Bumper Beam Design

Questions?

For a copy of *Steel Bumper Systems for Passenger Cars and Light Trucks*

Visit [www.AutoSteel.org](http://www.AutoSteel.org)
Thank You / For More Information

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www.AutoSteel.org

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