Optimized Steel Solutions for Roof Strength Using AHSS

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Outline

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- Optimization Without Design Change
- Design Change with Steel Inserts
- Optimization With Design Changes
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- Summary
• In August 2005, NHTSA proposed to increase the roof strength requirement under FMVSS216 from 1.5 to 2.5 times unloaded vehicle weight (UVW).

• The combination of occupant safety and the new fuel economy standard presents a challenge to automakers to meet the increased roof load requirements with the least weight and cost penalties.

• Advanced High Strength Steels are being effectively utilized for vehicle weight reduction while maintaining or improving safety, durability and NVH performance.

• This study focuses on steel only design solutions with the use of AHSS and CAE optimization technology.

• The target is to achieve a roof strength of 3 times UVW within 4.5 inch (114mm) load platen travel, 20% safety margin over the new FMVSS 216 requirements.
Cab Mass: 500.1kg
Load Factor: 3.05
(Nylon Inserts are located in the A-Pillar and C-Pillar)
• Built a baseline model from the A/SP MEARS phase 1 model with nylon inserts
• Removed nylon inserts and unnecessary contact definitions
• Increased time step (1.0 → 1.3 μs) and moving speed (1 → 3 m/s) of the rigid plate
• Decreased the CPU time from 15 hours to 3 hours with 4 CPUs for each run
Create a Reduced Model for Optimization

Gauge and Material (AHSS) Optimization w/o Design Change

Add Steel Inserts to Improve Crush Load

Update the Model with Optimal Steel Inserts

Gauge and Material (AHSS) Optimization With Optimal Steel Inserts

Concept Designs
AHSS Grades

![Stress-Plastic strain graph showing different AHSS grades including HSLA350, DP590, DP780, DP980, and Boron1550.](image-url)
### Parts for Optimization

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Material</th>
<th>Gauge Range (mm)</th>
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</thead>
<tbody>
<tr>
<td>A_Pillar_Inner</td>
<td>HSLA350 - Boron1550</td>
<td>0.6 - 2.2</td>
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<tr>
<td>A_Pillar_Rnf</td>
<td>HSLA350 - Boron1550</td>
<td>0.6 - 2.2</td>
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<td>Roof_Bow</td>
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<td>Roof_Rail_Inner</td>
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<td>Roof_Rail_Outer</td>
<td>HSLA350 - Boron1550</td>
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</table>

- **13 parts for material and gauge optimization w/o design changes**
- **Optimization software:** HyperStudy and LS-Dyna
- **Optimization objective:** minimum mass
  
Constraints: roof crush load factor > 3.0
Optimization Results – With Boron1550

Best

Iteration Number

Mass (kg)

Crush Load Factor

Cab Mass

Crush Load Factor

Optimization Results – With Boron1550

www.autosteel.org

www.autosteel.org
Optimization Results – With Boron1550

Cab Mass: 501.6kg
Load Factor: 3.00
Optimization Results – No Boron1550

Cab Mass: 505.6kg
Load Factor: 2.98
Plastic Strains on Roof Structures
Steel Inserts In Roof Rails

Insert Case #1

Section Cut

Insert Case #2

Section Cut

Graph:

- No_Roof_Rail_Insert
- Roof_Rail_Insert_#1
- Roof_Rail_Insert_#2

Crush Distance (mm)

Load Factor
Roof Bow Location

Original Location

90mm Forward

www.autosteel.org
Reinforcement at C-Pillar

Reinforcement DP980 or Boron1550
Tube at C-Pillar

1.5mm DP590

www.autosteel.org
Reinforcement Tube at A-Pillar

Reinforcement - Tube DP780

![Graph](chart.png)
A-Pillar Extended

After Extension
Roof Crush Performance With Steel Inserts

- Add C-Pillar Reinforcement
- Remove Rear Header Upper
- Add A-Pillar Reinforcement Tube
- Extend A-Pillar

![Graph showing load factor vs. crush distance with steel inserts]

![Diagram of vehicle roof structure with steel inserts]
Optimization Results –
With Boron1550 & Steel Inserts

![Graph showing Cab Mass (kg) and Crush Load Factor vs Iteration Number]

- Cab Mass (kg)
- Crush Load Factor

Best
Optimization Results – With Boron1550 & Steel Inserts

Cab Mass: 496.6kg
Load Factor: 3.00
Optimization Results – With Steel Inserts, No Boron1550

Cab Mass: 501.3kg
Load Factor: 3.00

THK: 1.41mm
MAT: DP590

THK: 0.86mm
MAT: DP590

THK: 0.71mm
MAT: DP980

THK: 0.76mm
MAT: TRIP780

THK: 1.26mm
MAT: DP780

THK: 1.23mm
MAT: DP980

THK: 0.60mm
MAT: DP590

THK: 0.90mm
MAT: DP780

THK: 0.60mm
MAT: DP780

THK: 0.60mm
MAT: DP590

THK: 1.22mm
MAT: DP980

THK: 0.76mm
MAT: TRIP780

THK: 1.65mm
MAT: TRIP780

THK: 1.60mm
MAT: DP980

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## Design Comparisons

<table>
<thead>
<tr>
<th>Components</th>
<th>A/SP Phase I Nylon Inserts Optimized</th>
<th>Optimized To DP980</th>
<th>Optimized To Boron1550</th>
<th>Steel Inserts and Optimized To DP980</th>
<th>Steel Inserts and Optimized To Boron1550</th>
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</table>
Summary

• Steel inserts at A-pillar lower and C-pillar upper are effective to improve roof crush performance for the B-pillarless pickup truck.

• The optimized steel only design meets the new roof strength regulation with 3.5kg mass savings compared to the A/SP phase I nylon insert design, and potential cost savings can also be achieved.

• Using hot-stamped boron steel for A-pillar, C-pillar and roof rail for roof crush offers about 4kg more mass savings than using DP steels.