Achieving Lightweight, Cost, and NVH Targets Using Quiet Steel® in Body Panels

Billal Bazzi
Material Sciences Corporation
Agenda

• Standards and Conflicting Targets
  – Body panels

• Quiet Steel® Value Proposition
  – Mass and Cost Reductions
  – Quiet Steel® vs. Aluminum
  – Quiet Steel® vs. Alternative NVH Treatments

• Panel Optimization Using Quiet Steel®

• Case Study: Future Steel Vehicle
  – MSC Stiffness and NVH Analysis
  – US Steel Global Stiffness and Crash Analysis
Are Federal Regulations Weighing OEM’s Down?

• Government CAFÉ Standards
  - Today  27.3 mpg
  - 2016  35.5 mpg
  - 2025  54.5 mpg

• Conflicting Targets for OEM’s:
  - Less...Mass – Cost – Vehicle Size/Packaging
  - More...NVH
Quiet Steel® achieves mass reduction targets for underbody panels without increasing cost, degrading NVH performance, adding supplemental NVH treatments or creating package space issues.
System Level Cost Savings

- **Existing Systems:**
  - Steel panels
  - NVH treatments

- **Standard Steel**
- **PCL Doubler**
- **Acoustic Treatments (LASD...)**
System Level Cost Savings

QUIET STEEL vs. Standard Steel

- Eliminate parts
- Reduce mass
- Eliminate assembly labor
- Superior performance
- 100% recyclable
System Level Cost Savings

- Quiet Steel® can Help Achieve Conflicting Targets:
  - Reduce Mass
  - Reduce Cost
  - Improve NVH performance
  - Minimize Package Space

- Eliminate parts
- Reduce mass
- Eliminate assembly labor
- Superior performance
- 100% recyclable
What is Quiet Steel®?

- Engineered composite consisting of a viscoelastic layer core among layers of Steel
- Several different polymer cores available and chosen based on specific application frequency, operational temperature, forming, durability requirements and corrosion resistance of the finished part
  - 7 different polymer cores have been sold commercially for damping applications
- Laminate is highly formable, completely weldable and can be painted

![Diagram of Quiet Steel laminate](image)

- Various coatings available (pre-paint, EG, galvaneal, phosphate, etc.)
Automotive NVH Frequency Range

Structure Borne Noise (FEA)

Airborne Noise (SEA)

Response

Global Stiffness

“Low”

~ 150 Hz

Local Stiffness + Damping

“Mid”

~ 1000 Hz

Absorption + Mass + Damping

“High”

~ 10,000 Hz

Quiet Steel

Log Frequency

~ 150 Hz

~ 1000 Hz

~ 10,000 Hz

Response
Average Value Proposition comparing **Steel + NVH Treatments** to **Quiet Steel®**

<table>
<thead>
<tr>
<th>Average Steel Thickness (mm)</th>
<th>Average QS Thickness (mm)</th>
<th>Average Upgauge (mm)</th>
<th>Average Upgauge (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.92</td>
<td>1.05</td>
<td>0.14</td>
<td>15%</td>
</tr>
</tbody>
</table>

Average Savings:
- Weight: 5.45 lbs
- Cost: $4.66

Price / lb of Quiet Steel® is equivalent to that of Steel + NVH Treatments. NVH targets using Quiet Steel® can be achieved with less weight, thus providing the cost savings as well.
Average Value Proposition comparing **Steel + NVH Treatments** to **Quiet Steel®**

<table>
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<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>0.80</td>
<td>1.04</td>
<td>0.24</td>
<td>30%</td>
</tr>
</tbody>
</table>

Average Savings:
- Weight: 3.67 lbs
- Cost: $3.61

Up-gauging can be reduced through optimizing part design for Quiet Steel early in the development cycle; thus, providing greater mass/cost savings.
Despite the 30% up-gauge, Quiet Steel® still provides weight and cost savings as it eliminates the need to use other heavy NVH treatments such as PCL and bake-on-mastic.

Up-gauging is typically needed to meet the stiffness requirements of an existing monolithic steel part design where geometry cannot be changed.

Quiet Steel® up-gauging can be minimized by optimizing part design for the use of laminate early in the design stage, thus, providing even higher weight and cost savings.

<table>
<thead>
<tr>
<th>Up-gauge (mm)</th>
<th>Average Weight Savings (lbs)</th>
<th>Average Cost Savings ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30%</td>
<td>3.67</td>
<td>$3.61</td>
</tr>
<tr>
<td>20%</td>
<td>5.20</td>
<td>$5.64</td>
</tr>
<tr>
<td>10%</td>
<td>6.73</td>
<td>$7.68</td>
</tr>
<tr>
<td>0%</td>
<td>8.26</td>
<td>$9.71</td>
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</tbody>
</table>
Average Value Proposition comparing Steel + NVH Treatments to Quiet Steel®

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<tr>
<th>Average Steel Thickness (mm)</th>
<th>Average QS Thickness (mm)</th>
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<th>Average Upgauge (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.88</td>
<td>1.03</td>
<td>0.15</td>
<td>17%</td>
</tr>
</tbody>
</table>

Average Savings for per target panel:
- Weight: 3.96 lbs
- Cost: $3.93

Average Savings for 5 target panels per vehicle (Dash, Cowl, Floor, Left & Right Wheel Wells) with up-gauging:
- Weight: 14.30 lbs
- Cost: $15.83
Lower Mass Substitutes for Steel can:

- Increase complexity and part/system cost
- Degrade acoustical performance if not used in conjunction with additional NVH treatments
  - added cost, mass and packaging issues
- Require up-gauge to maintain structural performance
  - packaging issues
Assumptions:
- 18 lbs steel dash panel, 1 mm thick.
- Aluminum panels same NVH treatments as steel panels.
- Up-gauge of 100% to 200% needed to meet the airborne NVH targets (mass law).

Quiet Steel® Provides the Most Cost and Mass Efficient Solution
- Need 4-6 mm of LASD with 65% coverage to have similar performance as Quiet Steel.
- This corresponds to a 60-90% increase in weight.
With a 0.4 mm constraining layer & 8.5% coverage, the patch is effective for some modes, (not all).
Objective:

Identify the Structureborne and Airborne NVH benefits of using Quiet Steel® in the body structure compared to standard steel with NVH treatments.
## Structureborne NVH Analysis

### Dash – Quiet Steel® vs. Solid Steel

**Driver’s Ear Sound Pressure Level (dBA)**

#### Delta dBA based on RMS

<table>
<thead>
<tr>
<th>Frequency [Hz]</th>
<th>20-100Hz</th>
<th>100-200Hz</th>
<th>200-300Hz</th>
<th>300-400Hz</th>
<th>400-500Hz</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>-0.3</td>
<td>-0.4</td>
<td>-0.4</td>
<td>-2.1</td>
<td>-5.1</td>
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</tbody>
</table>
Airborne NVH Analysis

Sound Transmission Loss of Dash – Test and SEA

Higher is better
Recommended Quiet Steel® Package

- Optimized Quiet Steel® Package
- Next Step: OEM to run full vehicle model
Case Study: Future Steel Vehicle

• MSC NVH analysis:
  – Quiet Steel Design Optimization
  – Low Frequency Structureborne Analysis
  – High Frequency Airborne Analysis (SEA)

• US Steel Full Vehicle Analysis:
  – Crash
  – Bending and Torsional Stiffness
Future Steel Vehicle – Panel Selection

- Dash Panel
- Tunnel Side Panel
- Wheel House Inner

www.autosteel.org
Low Frequency Structureborne Analysis

High Frequency Airborne Analysis (SEA)

3 Configurations:
- Solid Steel (SS)
- Quiet Steel (QS)
- Quiet Steel Optimized (QS Opt): same thickness, optimized geometric stiffening.
Dash Stiffness Optimization

Lower is stiffer.

QS Opt and bare steel configurations have the same stiffness.
Dash SEA Analysis

Higher is better

Frequency, (Hz)

STL, (dB)

Higher is better

Formation Effect, ~2 dB

Edge Radiation Effect

Coincidence Effect

SS(6.86 kg)  QS(6.86 kg)  QSOpt(6.86 kg)
Analysis Results

- An Optimized Quiet Steel® design:
  - Meets the stiffness requirements
  - Improves structureborne (mid frequency range) and airborne (high frequency range) NVH performance.
Crash and Global Stiffness Analysis

Analysis

NCAP
IIHS 40% ODB
Rear Impact
Bending Stiffness
Torsional Stiffness
Mode Analysis

Three materials are evaluated for the three panels being considered for quiet steel.

1) FSV Baseline line (Bake hard)
2) Mild Steel at same gauge as baseline
3) Mild Steel Quiet Steel® with total gauge same as baseline (i.e. two sheet bonded together with each sheet ½ baseline gauge modeled as shown on previous slide)
Global Stiffness Analysis

Model info: W:\fsy\FSY\Normal_modes\laminates\zero\FSY_BMW_V5_Normal_modes.dat
Result: W:\fsy\FSY\Normal_modes\laminates\zero\FSY_BMW_V5_Normal_modes.op2
SUBCASE 1: Model=0,Frequency= 5404±001Hz
Frame 4

54.0 Hz
# Global Stiffness Analysis

<table>
<thead>
<tr>
<th></th>
<th>Bending Stiffness (kN/mm)</th>
<th>Torsion Stiffness (kN-m/deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target</td>
<td>Model Results</td>
</tr>
<tr>
<td>Steel</td>
<td>12</td>
<td>15.59</td>
</tr>
<tr>
<td>Quiet Steel®</td>
<td>12</td>
<td>15.27</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
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<th>Bending Frequency (Hz)</th>
<th>Torsion Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Target</td>
<td>Model Results</td>
</tr>
<tr>
<td>Steel</td>
<td>&gt; 40</td>
<td>60.4</td>
</tr>
<tr>
<td>Quiet Steel®</td>
<td>&gt; 40</td>
<td>60.0</td>
</tr>
</tbody>
</table>
Crash and Stiffness Summary

• Quiet Steel® panels analysis results:
  – Vehicle’s crash performance and global stiffness were only slightly decreased.

• Next Steps:
  – Run crash and global stiffness analysis on optimized Quiet Steel® designs.
Conclusions

• Quiet Steel® can provide mass and cost reductions, while meeting or exceeding NVH targets, without changing the packaging space.

• The key to achieve these targets:
  • System approach
  • Develop and evaluate Quiet Steel® panels in early design stages
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