NVH TECHNOLOGY IN THE BMW 1 SERIES

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• Introduction
• Hybrid Interior Noise Synthesis Approach
• Measurements on Vehicle
• Panel CAE Model Creation
• Panel Optimization for NVH and Crash
• Conclusion
Introduction

- Lighter vehicles for reduced CO2 emission
- Preservation of safety and comfort
Objective: Lightweight steel solution for noise performance

Panel investigation using Test and CAE Hybrid Approach

Candidate vehicle / panel
- Compact and comfortable vehicle
- Firewall on direct engine noise path

Firewall of BMW Series 1
Step 1: Vehicle measurement

Step 2: Panel measurement

Step 3: Panel CAE model

Step 4: Panel modification

Step 5: Modified panel in vehicle

Project Framework
Engine Noise Structure Borne
0 – 400 Hz
INTERIOR NOISE SYNTHESIS

TEST
Original

HYBRID
Noise Improvement Evaluation
In full Vehicle

Panel
Cavity geometry

CAE
Design Modification

Optimized Firewall

Design Modification

(Physical panel manufacturing is not needed)
• On Vehicle
  – Acoustic Source Quantification
    • Measure firewall and cabin response to structural excitation
    • Isolate firewall contribution
    • Estimate other panel contributions
  – Acoustic characterization of passenger cabin

• On Panel
  – Trim package evaluation
  – Structure characterization

FE model validation
ACOUSTIC SOURCE QUANTIFICATION
• Firewall and floor are the dominant steel structures in the low frequency range

• Floor dominates the higher frequencies
ACOUSTIC CHARACTERIZATION OF PASSENGER COMPARTMENT

- Acoustic-acoustic FRF measurements
- Measure cabin dimensions

Build and validate acoustic FE model
ACOUSTIC CHARACTERIZATION OF PASSENGER COMPARTMENT

Modes of firewall in range of interest

Mode 1 – 58 Hz  
102 Hz  
141 Hz  
144 Hz
Components purchased from BMW dealer

Roving hammer measurements:
- Components
- Assembly
Scanned firewall components

Firewall is spot-welded structure with full vehicle boundary conditions + Trim

Passenger cabin FEM

Firewall structure coupled with acoustic model
• Structural response shows the model is successful for 40 Hz – 300 Hz

• Vibro-acoustic CAE model catches the mid-range firewall contribution (80 Hz – 200 Hz)

• Test is under predicting due to small number of measurement locations on firewall
Use CAE model to identify structural weak points:

- Lower firewall
- Firewall region behind the beam

Mode Contribution Analysis

Element contribution analysis
• 40+ modifications investigated

• Optimized design
  – Modified transverse beam with new M-shape, reduced thickness, holes and Tailored Welded Blank
- Static analyses
- 2 load cases: front and side

**Frontal Crash**

5000N

5000N

**Side Crash**

5000N

5000N

**Graphs**

- Frontal Crash Maximum displacement [mm]
  - Original design
  - Final design

- Lateral Crash Max Displacement [mm]
  - Original 1.73 mm
  - Final design
MODIFIED PANEL INFLUENCE ON OVERALL VEHICLE NOISE

- 0.90 dB
- 1.64 dB

Firewall contribution to sound
Full vehicle sound pressure

Initial cabin noise
Modified cabin noise
## PERFORMANCE IMPROVEMENT SUMMARY

<table>
<thead>
<tr>
<th>Original</th>
<th>Advanced Steel Solution</th>
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<tbody>
<tr>
<td>BMW1 Firewall</td>
<td>TWB + Beads + M-Shaped Beam + Holes</td>
</tr>
<tr>
<td><img src="image1.png" alt="Original BMW1 Firewall" /></td>
<td><img src="image2.png" alt="Advanced Steel Solution BMW1 Firewall" /></td>
</tr>
<tr>
<td>0.7mm</td>
<td>0.7mm</td>
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<tr>
<td>1.7mm</td>
<td>1.5mm</td>
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<tr>
<td>1.9mm</td>
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<tr>
<td>Panel + Beam 8.43 kg</td>
<td>Panel + Beam 8.19 kg</td>
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<tr>
<td>Damping sheets 0.40 kg</td>
<td>Damping sheets 0 kg</td>
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<tr>
<td>Weight reduction 0.64 kg (5.1%)</td>
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<tr>
<td>Noise level −0.90 dB (10 − 400Hz)</td>
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CONCLUSIONS

• Hybrid Interior Noise Synthesis
  – Efficient, simple and flexible
  – Potential to be used at early design stages
  – Short calculation time, allows a large number of iterations and in-depth sensitivity analysis

• Elaborate steel designs are successful at
  – Achieving better noise performance
  – While improving the mass
  – Not compromising crashworthiness
  – 1 dB improvement on firewall contribution of high end vehicle

• For even larger improvements...
  – Address NVH earlier in the design process