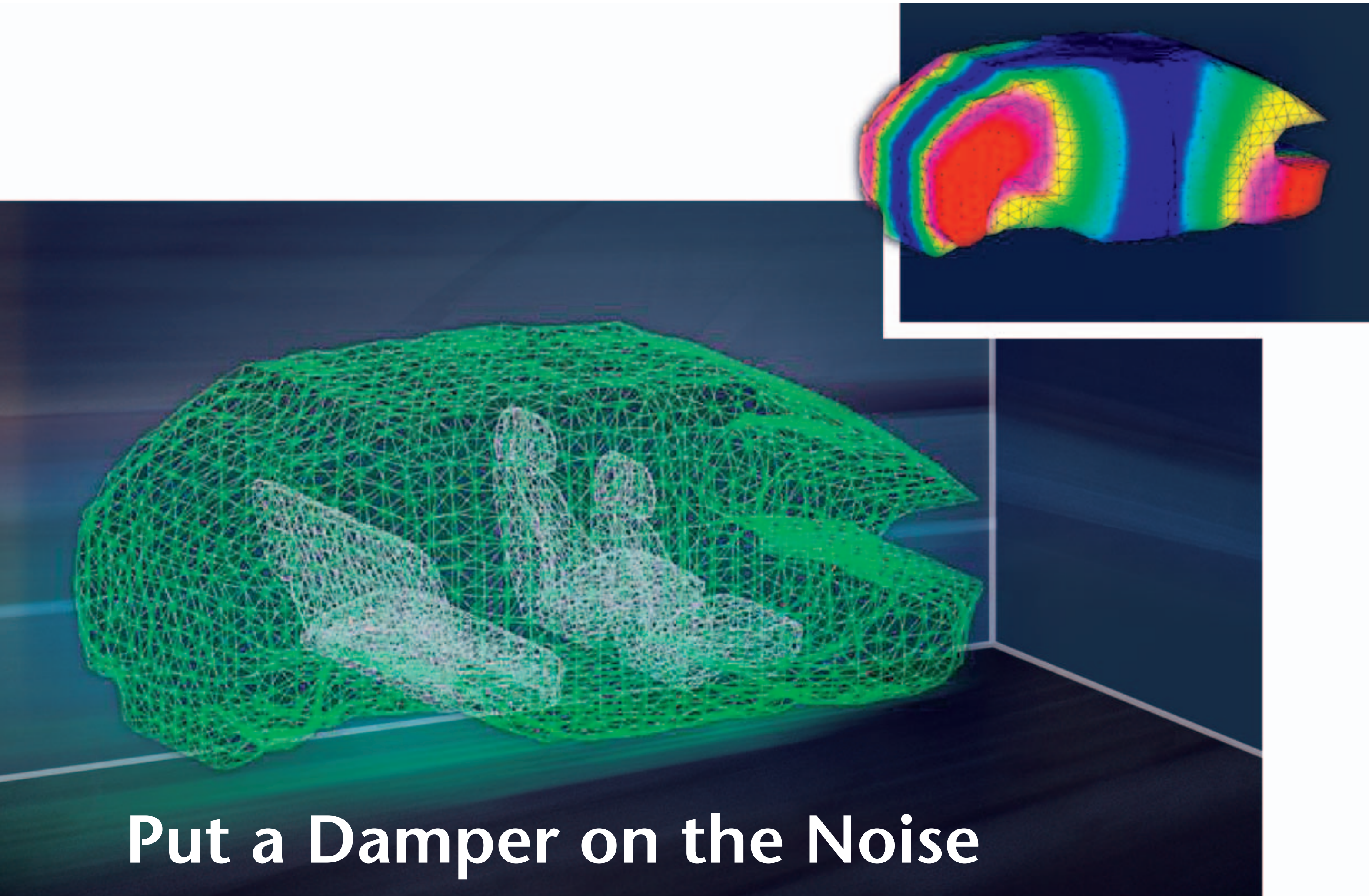

Put a Damper on the Noise

Using Laser Vibrometry to Optimize Damping Material Layout to Reduce Vehicle Body Interior Noise & Structural Vibration

A comprehensive hybrid technique was developed to optimize the application of damping materials on vehicle bodies. The technique used finite element analysis (FEA) and experimental measurements to complement each other. In this example, it was used to suppress floorpan vibration and the associated radiated noise. By optimizing the application of damping material, a 3 – 5 dB reduction in the floorpan vibration level was achieved while saving 10 % in material volume and mass. The optimized layout was validated on a body-in-white using a scanning laser vibrometer.

Introduction

A process was developed to optimize the application of liquid damping material on an automotive platform. The approach consisted of four steps (Figure 1). First, the high vibration areas of the vehicle floorpan were determined, indicating the areas in which damping materials are needed. Second, the vehicle transfer functions were measured to quantify the amount of noise resulting from floorpan vibration. Third, the material layout was optimized using FEA. Finally, an optimized product was measured to validate the predicted vibration performance.

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Panel Vibration Measurements

A Polytec Scanning Vibrometer was used to measure the vibration response of the floorpan. To cover the entire vehicle floorpan surface, the laser beam was bounced off a static mirror placed at 45 degrees under the vehicle (Figure 1). Some of the measurement points used during the laser scan are shown in Figure 2. Small magnetic retro-reflectors were placed on the floorpan to ensure good signal quality at each measurement point.

Two shaker locations were used to stimulate vibration modes in the floorpan. The laser scan was completed by exciting one shaker at a time. Each shaker applied a swept sinusoidal force on the vehicle body from 20 to 300 Hz.

At each sampling point, the scanning laser vibrometer measured a frequency response function (FRF) between the vibration and the excitation force. Laser vibrometer mappings of the FRFs (not shown) revealed the highest vibration areas are in the rear half of the vehicle. Concentrating the damping material in these areas was optimal and minimized structure-borne noise. Conversely, the laser vibrometer also identified low vibration areas where less damping material was needed to suppress the structure-borne noise; thereby, saving material, weight and cost.

Floorpan Vibration to Interior Noise Levels

Compared to the body-in-white for the vibrometer measurements, a fully assembled vehicle was used to determine the amount of noise originating from the vibrating floorpan that reached a driver's ears. First, the interior acoustic modes were measured and calculated by FE modeling (title image) and compared to direct interior sound level measurements. Similar to structural vibration modes, these acoustic modes

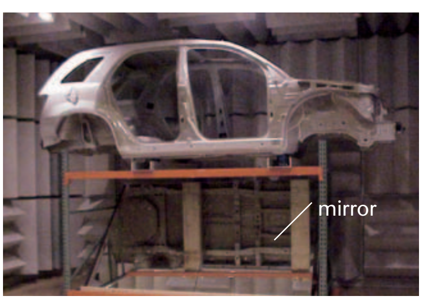

Figure 1: Laser scan test setup.

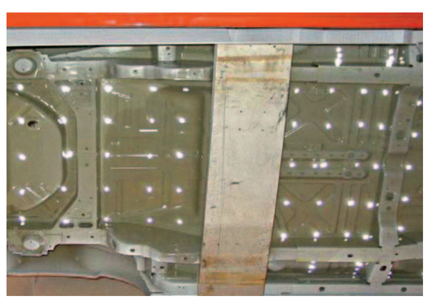

Figure 2: Points measured in laser test.

highlight the most important acoustic frequencies for modeling. Then, the transfer function between the floorpan vibration and the resulting interior cavity noise was determined by aligning the shakers to the previously used attachment points. From these studies, interior airborne noise at driver ear level was related to floorpan vibration.

Optimization Using Finite Element Analysis

Once the transfer function was understood, a finite element technique was used to study the vibration response of the vehicle floor. This technique identifies the "noisy" region in the undamped floorpan. Confidence in the finite element model came from comparison to the original vibrometer measurements and an understanding of the acoustic attenuation properties of the sprayable damping material. Then, the model was used to design the optimal application of damping material to suppress interior noise levels.

Validation Testing

The improvement in performance predicted by the FE modeling was verified by repeating the vibrometer measurements. In Figure 3, the average FRFs are shown for all measurement points on the floorpan based on the laser vibrometer data. A comparison of the vibration level with and without damping material indicates an improvement of up to 15 dB is realized with the current damping treatment beyond 100 Hz.

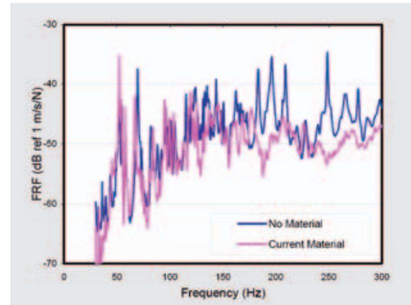

Figure 3: Current damping performance.

Figure 4: Vehicle body with optimized damping material layout.

The optimized layout determined by FEA was created by removing or adding material to a vehicle body applied with the current layout. In Figure 4, the vehicle body is shown with material removed in areas of low vibration and material added in areas of high vibration. The vehicle was then tested using the laser vibrometer to measure the vibration level.

The optimized damping material layout results in a vibration reduction of about 1 dB for the front shaker location and a reduction of about 3 – 5 dB for the rear shaker location (Figure 5). This performance increase was achieved while reducing the damping material mass by 0.8 kg (10 %) and the wet volume by 0.24 gal (10 %).

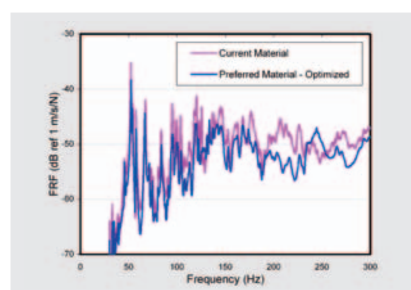

Figure 5: Optimization results.

Conclusions

This study demonstrated the ability to improve the performance of liquid-applied damping material while simultaneously reducing its usage. Through optimization, the average vibration level was reduced by 1 to 5 dB while providing a 0.8 kg mass savings. This volume reduction of 0.24 gallons per vehicle results in a savings of approximately $ 215,000/year to the auto body manufacturer. Ideally this optimization should be part of the initial design and placement of the damping material prior to a vehicle launch.