How BAIC optimized car-body damping by simulation

Based on interviews with Wang Zhiwen, Director, Lightweight Tech. Dept., Beijing Automotive Technology Center, and Wu Lie Nhv Dept., Director and Chief Engineer, Baic Motor Research Institute
Background

Damping materials are widely used to reduce vibration and noise. In order to provide passengers a comfortable environment with minimal vibration and noise, these materials are attached to the body and floor of cars to minimize body vibration and keep the body structure from generating and radiating excessive noise. Their reasonable arrangement is one of the key factors to ensure NVH performance.

There are many types of damping materials for automobiles: asphalt, rubber, and water-based damping paint are among those commonly used. These materials vary in cost, attachment methods, environmental friendliness and damping performance. Their selection and use directly affect the NVH performance, manufacturing costs and fuel economy. Therefore, the choice of their arrangement and thickness challenges the lightweight department and NVH team, who must select the right controlled weight material while ensuring the performance of the entire vehicle.
Industry challenge

Damping structures may be installed on floors, trunks, wheel covers, doors, and other parts of cars to reduce vibration and noise.

“Previously, rules of thumb and the maximum strain energy method were our only approaches toward floor damping design. Without technical means of accurate damping simulation, we were not sure whether a design was optimal until it was experimentally verified,” said Wu Lie, NVH Dept. Director and Chief Engineer, BAIC Motor Research Institute. “If the acoustic performance of a prototype car was disqualified by the physical verification, we empirically installed more damping materials on the car. Nevertheless, hardly could we tell if this approach was most effective and cost-efficient.”

In the automotive industry, common practice involves simulation using the modal strain energy (MSE) method to locate the points where the strain energy is the highest, before large pieces of damping materials are attached to such floor points where the sheet metal is flat enough to allow for such operation. However, we do not know if the points so located hit real-life loads such as road and engine noise, and if the design can control vibration and noise. When it comes to simulating the NVH performance of damping materials, Chinese NVH teams generally assume the non-structural mass as damping layers and define empirical modal damping for the body structure to approximate the effect of materials. Far from mapping the damping design, this cannot directly verify the ultimate effect of the design.

“To meet ever-increasing competition on the automotive market, we are in urgent need of a CAE method to accurately simulate the NVH performance of damping materials,” said Wu. “The method should enable us to optimize the materials in response to the physical load and control the costs while ensuring vehicle performance.”

MSC Solution

Accurate simulation of damping

Damping materials typically feature a damping loss factor that varies by frequency. Therefore, a simulation model must emulate the damping that the materials bring to the structure where they are attached, in addition to reflecting the attachment between the materials and the structure. Using the Young modulus to define their loss factor, Actran accurately simulates the effect of materials with solid shell elements that map the damping layer.

Before modelling the damping of a car body, a box is tailored for simulation and correlation. Damping materials are applied on a panel of the box and a shaker is exciting the structure while the sound pressure response in the box is measured.

“Actran allows us to comprehensively evaluate how damping materials can help reduce vehicle weight and improve NVH performance. Thanks to simulation-based optimization and test verification, the materials installed on a certain car model were reduced by more than 25%, cutting the cost by more than RMB10 per vehicle.”

Wang Zhiwen, Director, Lightweight Tech. Dept., Beijing Automotive Technology Center

Simulation model and test picture of a tailored box to which damping materials are attached
Optimal damping arrangement

Actran Energy Analysis (EA) approach automatically reduces the system into segments, assembles mass and stiffness matrix (obtained using MSC Nastran) in each segment, and calculates the energy per space and frequency range. This approach features more efficient calculation than the traditional FE method and makes it easy to study the impact of each segment on the entire system.

The EA approach allows one to quickly analyze how the interior noise in a car is sensitive to the damping under real-life load. Therefore, the position where the damping has the greatest effect on interior noise is identified. Then, the initial design may be optimized by reducing the damping at insensitive positions or increasing the one at sensitive positions.

Using the optimization package NLopt embedded in Actran and secondarily developed scripts, we optimized the thickness of the retained damping segments. The optimal thickness of each damping piece that ensured the initial acoustic performance was identified.

Result

The test verification of road noise proved that the new damping design provided the same interior noise as the initial one. “Actran-based damping optimization for car body and floor enabled us, for the first time, to correlate the interior noise to the damping position and materials, and to optimize the positions and thickness of damping materials. The materials installed on the floor were reduced by more than 25%, cutting the cost by more than RMB10 per vehicle,” said Wang. “By introducing Actran, we made our first accurate simulation of damping materials. The Actran-based optimization methodology enables us to reduce weight and optimize noise. This practical and flexible approach allows us to comprehensively evaluate how damping materials can help reduce vehicle weight and improve NVH performance.”