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Squeak & Rattle Simulation

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A New Approach to Developing Automotive Interior Parts

Squeak & Rattle performance is an increasingly important component to customer satisfaction in the automobile industry. Normally Squeak & Rattle performance in a new car is tested during the validation phase prior to the start of production. In order to reduce the number of Squeak & Rattle issues during validation, a robust design is required. To achieve „right the first time" designs for GM projects, thus avoiding unnecessary development loops, a comprehensive Squeak & Rattle simulation tool was used. However, before the simulation tool can be used effectively, the correct representation of a part's dynamic behavior must be known. Therefore, a 3-D Scanning Vibrometer was used to measure the dynamic behavior of each interior car part in order to improve the modal correlation. The combination of the 3-D vibrometer data and the simulation tool has helped engineers achieve a better understanding of how to correctly assemble automotive interior parts to avoid disturbing squeaks and rattles.

Introduction

The production of squeaks & rattles (S&R) in the vehicle is a very complex noise phenomenon. A wide range of factors including material pairs, surface finishing, assembling, relative displacement between parts, tolerances, road load, and manufacturing, can influence amount of S&R . Only one of these factors - the relative displacement - can always be related to S&R issues. Therefore, it is important to focus on the relative displacement when trying to simulate the S&R phenomenon. In a typical vehicle, the instrument panel (see title photo) has the highest complexity of interior assemblies due to the number of different parts and instruments mounted together. In order to avoid S&R problems, the relative displacement between all these parts has to be controlled.

Parameter Definition

A detailed study of the instrument panel identifies a number of important parameters which must be represented in the simulation model in order to calculate the relative displacement (Figure 1). These parameters are valid for all interior assemblies regarding the S&R simulation. The global stiffness has a major impact on the relative displacement.

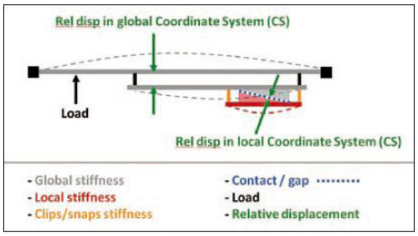

Figure 1: Parameter definition for S&R simulation model.

This impact is strongly related to the number and position of internal mounting points. The local stiffness together with the clips and snap stiffness is also important for the relative displacement. In addition to the stiffness, the local geometry, in the area where two parts can come in contact, has to be considered in the simulation. In addition, the applied load has a decisive influence on the S&R performance. A load level that is too low will probably not cause any S&R issue. A load level that is too high will always cause problems. Therefore, it is important to define a realistic load. The relative displacement is the output of the simulation, which is processed both in global and local coordinate systems.

Different types of analyses are applied during the development process. The output of these analyses is adapted to the detail level of the interior assembly:

- The modal analysis begins with a focus on the main structural parts.
- As the structure becomes more detailed, the transient analysis allows the study of relative displacement between the global structural parts due to a pulse load.
- Finally, the Squeak & Rattle simulation is performed on the complete detailed model, using a frequency response analysis in conjunction with the EdWare software from EDAG. Measured acceleration data is used as the load and the "SAR line" method is used to account for the local contact geometry when post processing the relative displacement.

Modal Analysis and Modal Correlation

The Opel Insignia instrument panel is a complex structure involving many plastic parts. Both the material data (e.g. Young's modulus) and the Finite Element (FE) representation of these plastic parts are not well-defined as compared to a steel body-in-white structure. Since the foam and foil together with the carrier structure are acting as a composite, the data from the material suppliers cannot be used for the simulation. Therefore, direct measurements and modal correlation work must be performed in order to improve the simulation capability.

To capture the global deformation of the structure, several accelerometers were used. The major result of the correlation was that only the lowest modes were represented correctly while higher modes did not correlate, showing that the data for the plastic material must be considerably modified.

Modal Correlation with the Aid of a 3-D Scanning Vibrometer

To improve the modal correlation on a global and on a local level, a Polytec 3-D Scanning Vibrometer was used for structural measurements (Figure 2). There are two significant advantages to this approach. The first advantage is the elimination of using relatively heavy accelerometers and the resulting mass loading. Retro-reflection tape can be used with the vibrometer, enabling the measurement of light-weighted trim parts. The second advantage concerns the greater number of points that can be measured compared to measurements using individual accelerometers where the number of channels is limited.

The initial results of this correlation work showed clearly that there is room to improve the linear simulation models on a local level. The improvement is related to a better understanding of exactly how to connect the parts to each other in the best way in the simulation model. The model enables the user to perform side studies at an early stage to give input to the design engineers on how the stiffness can be modified in the most effective way such as by using different mounting point locations or different materials (e.g. glass fiber reinforced). Design criteria includes both the modal frequencies and the mode shape continuity. By studying the mode shapes, the locations for additional ribs and reinforcements can easily be identified. Since the modal analysis can start very early in the design project, there is sufficient time to implement most of these reinforcements.

Figure 2: Operational deflection shapes of the instrument panel taken with the 3-D Scanning Vibrometer for modal correlation.

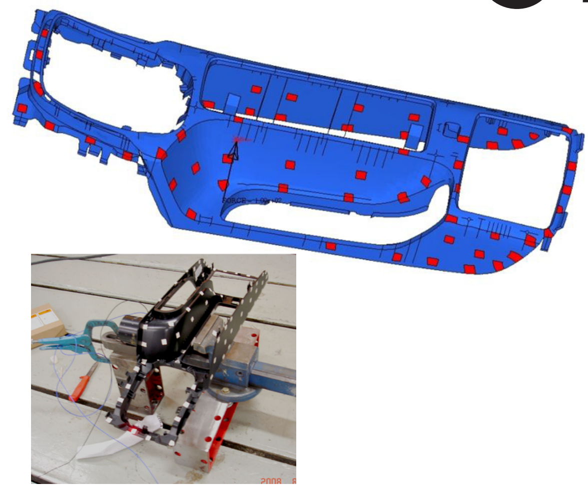

Figure 3: Simulation model and the trim part of the floor console held in a jig for vibrometer testing.

The Vibrometer Uniquely Enables Measurement of Light Weight Parts

Precision vibration measurements on light weight trim parts are made possible by the Scanning Vibrometer. Traditional approaches that use contact accelerometers adulterate the dynamic response with extra mass and stiffness. In Figure 3, the simulation model and the test setup for the Insignia's floor console trim part is shown. The results from the scanning vibrometer represent the first time that a displacement measurement on this part has ever been made. The data measured by the 3-D Scanning Vibrometer were exported in the UNV format and subsequently imported into LMS Test in order to extract the Eigen modes. Both measured and calculated modes were entered into LMS Vlab to perform a modal correlation analysis. This relatively simple FE model represented the dynamic behavior of the part with amazing accuracy. The first 10 Eigen modes had very good MAC values (Modal Assurance Criterion) better than 0.8 even when considering all measurement points (see Table and Figure 4).

Mode #	Simulation [Hz] Young's modulus 2130 MPa	Simulation [Hz] Young's modulus 2600 MPa	Test [Hz]	MAC value [-]
1	13.8	15.3	15.0	0.98
2	18.9	20.9	21.2	0.95
3	24.1	26.6	25.7	0.98
4	31.4	34.7	35.3	0.98
5	42.2	46.4	46.3	0.98
6	48.6	53.7	54.9	0.89
7	61.6	68.1	68.4	0.94
8	65.1	72.0	72.9	0.93
9	78.3	86.5	87.5	0.84
10	85.0	93.9	95.0	0.87

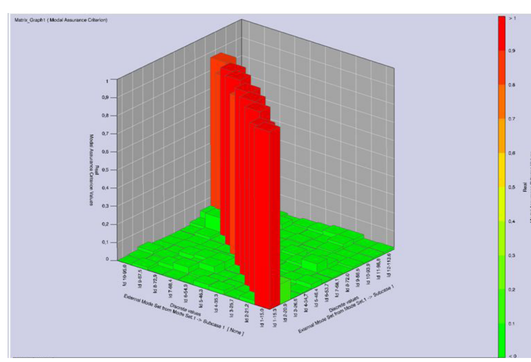

Figure 4: Plot of the MAC values of the modal correlation.

Conclusions

The purpose of the S&R simulation is to represent the dynamic behavior of the interior structure as accurately as possible in order to be able to relate the relative displacement to the actual S&R phenomenon. The results of the modal correlation show that the linear simulation model is capable of calculating the lowest global modes correctly using improved plastic material data (unsatisfactory correlation for higher order modes still persists). This capability also makes the modal analysis a powerful tool to support the interior design process at an early stage. In order to improve the modal correlation on a local level, a 3-D Scanning Vibrometer is used for measuring the dynamic behavior of the interior parts. This correlation leads to a better understanding of how to assemble the interior parts to minimize S&R issues.

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