FE Model Update

Field of Application

A Aerospace
B Audio & Acoustics
C Automotive
D Data Storage
G General Vibrometry
M Microstructures & -systems
P Production Testing
S Scientific & Medical
T Structural Testing
U Ultrasonics

The rear-axle-carrier (RAC) is the central part of the rear-axle construction on rear-wheel-driven BMW vehicles and serves as a support and isolation for the wheels and the differential. Finite Element Modeling (FEM) is used to optimize the design of the RAC and to guaranty superior performance. The model was validated using experimental modal analysis (EMA) and precision dynamic data measured with a 3-D Scanning Vibrometer.

Introduction

The 3-D Scanning Laser Vibrometer avoids the serious complication of traditional, contact accelerometers by eliminating sensor mass and stiffness that can load the structure. Additionally, the laser vibrometer allows for more measurement points giving much higher spatial resolution at lower cost with no labor needed to attach accelerometers. For a typical measurement, a total of 500 points on the structure (1500 FRFs) are used for the validation.

Experimental Setup

In Figure 1, a freely suspended RAC is shown. The excitation is produced by a shaker attached to a corner point on the structure and oriented such that all three global directions x, y and z experienced approximately the same degree of excitation. In this way, most modes of the structure could be properly excited with only one excitation location. The shaker excited the structure with a pseudo-random signal. The sample rate of the measurement was 2560 Hz and had a block length of 4096 samples. The excitation frequency band was set from 100 to 1000 Hz.

Experimental Results

The data obtained from the experiment was exported by the Polytec measurement software to the Matlab-based Structural Dynamics Toolbox (SDT) as a Universal File (UFF). Using the SDT, dynamic toolbox, dynamic analysis, including some advanced optimization algorithms, permit accurate modal parameter identification. A plot of the 500 nodes that were measured on the RAC with the vibrometer is shown in Figure 2. The model used to fit the data was based on normal modes and contained lower and higher residual terms. With the proper settings chosen, the pole-residue model was calculated and the poles and residues were optimized for the best fit. In the SDT, this is done with a non-linear least-squares optimization (minimization) process. The fit obtained with the pole-residue model is shown in Figure 3 for a representative transfer function.

The fit accurately follows the measurement data, especially near the resonance peaks. Noise at the anti-resonances in the higher frequency range shows the greatest departure from the fit.

Polytec GmbH
Optical Measurement Systems
Application Note
VIB-C-05

June 2008

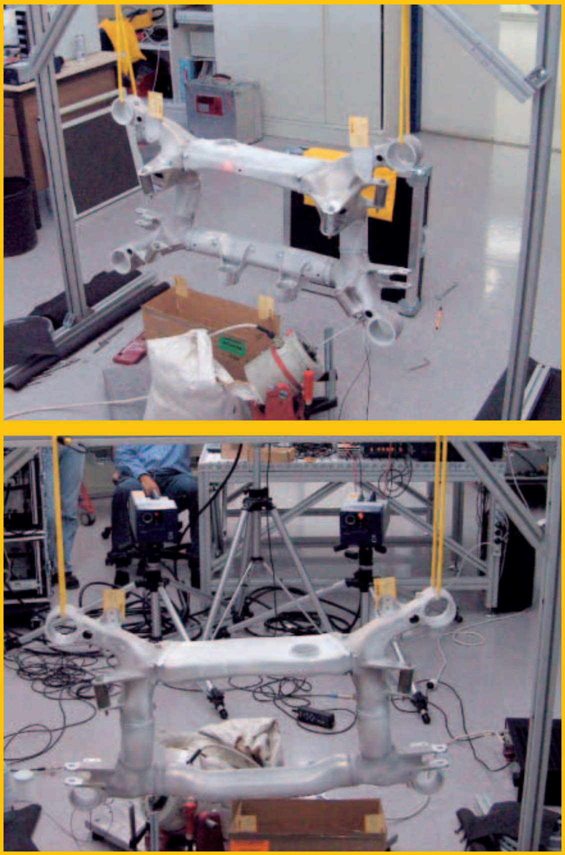

Figure 1: Measurement setup with suspended RAC, the shaker, and the 3-D Scanning Vibrometer heads

Figure 4: The FE model mesh

Description of the Finite Element Model

The finite element model of the RAC was created in Medina Software. The geometry was imported from a CAD-model used in the design of the RAC. The mesh (Figure 4) consists of duplex tetrahedron elements and in total the model contained approximately 1.3 million degrees of freedom.

The modal analysis was performed on the finite element model in NASTRAN by a Lanczos iterative solver. Using the FEM calculation, seventeen eigenfrequencies were found when frequencies were examined up to 1000 Hz.

Validation of the FE Model

At first, the eigenfrequencies from the experimental measurement were found to deviate from the FEM analysis by 2 %. A more detailed and objective statement on the accuracy of the model can be made by a modal assurance criterion (MAC) analysis, which is addressed in the remainder of this section.

To be able to correlate the mode shapes found from the finite element calculation with the vibrometer measurements, it was important to obtain the mode shapes at the same nodes in both models. To this end, the UFF 2411 file from the measurement was imported into the FE model, so that the grid of test nodes was "superimposed" on the FEM mesh. By inspection, 124 nodes from the model corresponding with measured nodes were then selected in such a way that the global shape of the RAC could be properly described. The MAC analysis in the Structural Dynamics Toolbox was redone and the results are shown in Figure 5.

As can be seen, the MAC values for the first 8 modes were excellent. Modes 10, 12, 13, 15, 16 and 18 also showed correlations of 85 % or higher. However, the MAC values of modes 9, 11, 14 and 17 were found to be rather low. It is suspected that this is due to a lack of excitation of mode 9, 11 and 14. This is supported by the small resonance response shown in Figure 5. Moreover, due to the limited spatial resolution, mode 13 and 14 have a high correlation already, as can be seen in Figure 5 (right), where the FEM modes are projected on each other.

Finally, mode 17 appears to be an "artificial" mode that originates from the test configuration. It is suspected that modes 16 and 17 are actually a single mode split into two modes due to a slightly asymmetric structure. This explanation is supported by the fact that the FE model predicts only one mode; this mode has a correlation of 85 % with mode 16 while the correlation with mode 17 is 50 %.

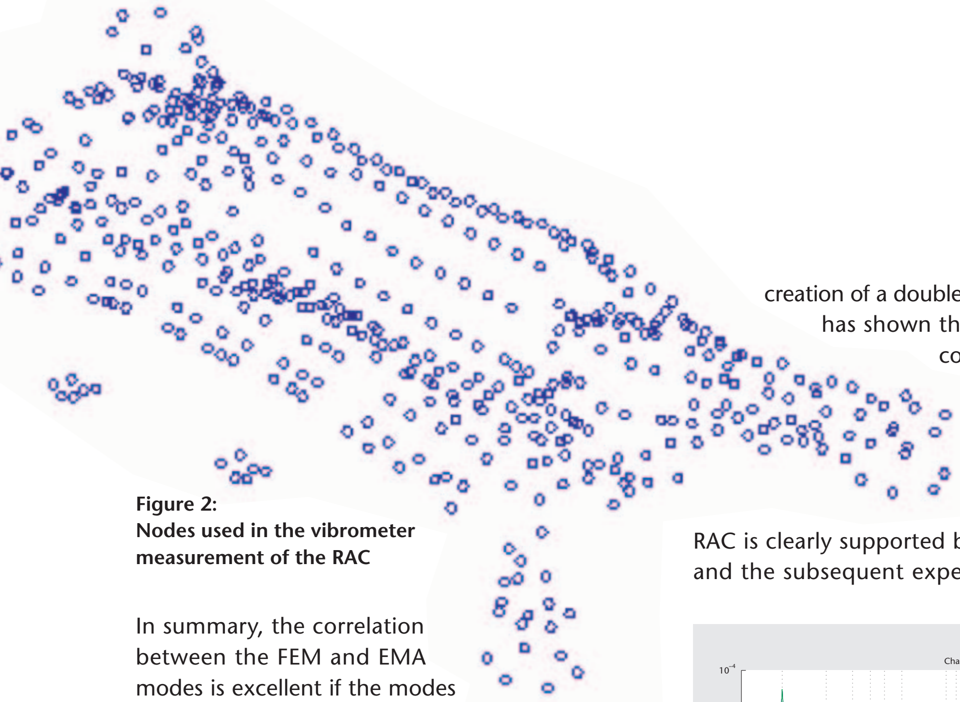

Figure 2: Nodes used in the vibrometer measurement of the RAC

In summary, the correlation between the FEM and EMA modes is excellent if the modes are associated with the strong peaks in Figure 6. This means, that all the important deformation patterns are present in both models.

Conclusions

The results of the EMA corresponded well with the FEM results. Of the 17 eigenmodes, 12 modes had a correlation of 90 % or higher and 10 modes even had MAC values of 95 % or higher. In general, the measured eigenfrequencies were a little higher than the calculated frequencies, probably due to inaccuracies in the geometry of the manufactured RAC, the influences of the test configuration and inaccuracies in the material model used by the FEM model. Only three modes had a rather low correlation. The discrepancies between model and measurement could all be traced back to deficiencies in the setup resulting in poor excitation of some modes and the creation of a double mode. This measurement has shown the potential of using non-contact, 3-D Scanning Laser Vibrometers for fast and efficient FE model validation. In our particular case, the finite element model of the RAC is clearly supported by the measurement data and the subsequent experimental modal analysis.

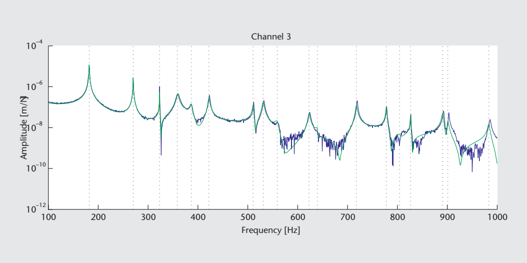

Figure 3: Fit obtained with real residues (channel 3)

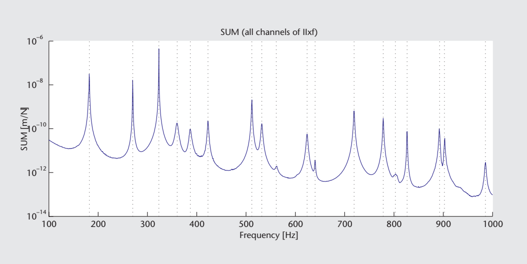

Figure 6: Fit obtained with real residues (all channels)

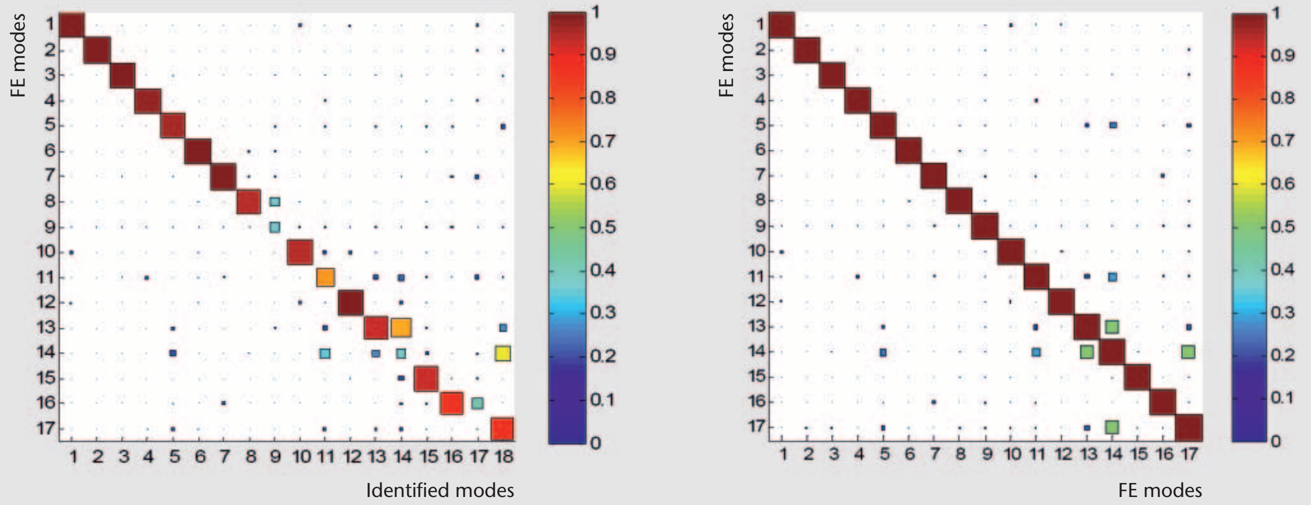

Figure 5: Results of MAC analysis for all nodes (left) and FEM modes only (right)

3-D Vibration Measurement Technology

Automated, Non-contact Full-Body Vibration Mapping

RoboVib Structural Test Station

RoboVib removes many of the limitations of traditional contact transducer methods. By mounting a 3-D Scanning Vibrometer to a multi-axis industrial robot, RoboVib is engineered to be a stable, auto-configurable 3-D vibration measurement station for whole body vibration mapping of complex-shaped objects. This unique combination of productive technologies can reduce test times for experimental modal analysis (EMA) from weeks to days and from days to hours. The points to be measured can be derived from Finite Element (FE) Models, thus facilitating Model updating. Due to the increased productivity, test fields and prototypes are used more efficiently, the results are faster available.

www.polytec.com/robovib

PSV-400-3D Scanning Vibrometer

The PSV-400-3D Scanning Vibrometer is the perfect measurement instrument for gathering three-dimensional vibration data from both simple and complex structures. It features an intuitive 3-D animation of the measurement results with separation of out-of-plane and in-plane vector components as well as a powerful data interface to Modal Analysis and FEM Software.

www.polytec.com/psv3d

For more information about the PSV-400-3D Scanning Vibrometer and automotive applications please contact your local Polytec sales engineer or visit our web pages **www.polytec.com/psv3d** and **www.polytec.com/automotive**

We gratefully acknowledge the support of D. de Klerk, M.Sc., and S. N. Vermeeren, B. Sc., both Delft University of Technology, in providing this application report featured in Polytec InFocus issue 2/2007.

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