EAN 2014
52nd conference on experimental stress analysis

Vibration Reduction of the Sheet Metal Structures

PETŘÍK Jan[1,a], KULHAVÝ Petr[1,b], PAŠEK Miloslav[2,c] and ŠAŠEK Jakub[2,d]

[1]Technical University of Liberec, Faculty of Mechanical Engineering, Studentská 2, 461 17 Liberec 1, Czech Republic

[2]Mecas ESI s.r.o., Brojova 16, 326 00 Plzeň, Czech Republic

[a]jan.petrik@tul.cz, [b]petr.kulhavy@tul.cz, [c]miloslav.pasek@mecasesi.cz, [d]jakub.sasek@mecasesi.cz

Keywords: Damping, vibration, sheet metal.

Abstract. This article describes the differences between experimental frequency response analysis and the approach to modeling the damping behavior. Vibration analysis of sheet metal structures with damping material like bitumen and foam evince the differences in frequency response which is used for validation of the material models. The separate material models of the structure and damping material is the benefit for predictive simulations.

Introduction

Vibration and noise damping of the sheet structures is the present issue not only for automotive producers. The main object is to provide a structure which reduces the negative effects of vibration causing the acoustic noise as a result of mechanical excitation. There are plenty of approaches to reduce structure vibrations. Passive vibration damping like sandwich structure of the metal and damping sheet is still the easiest possibility in term of the production cost. Three types of available common damping materials were used: polyurethane foam, polyurethane foam with aluminum foil and bitumen sheet. This article provides vibration analysis of possible materials fixed on the steel specimen surface and the proposal of the vibration response simulation.

Experiment

The description of the experiment is in Fig. 1. The influence of the damping material was described by the frequency response function as the transmissibility of acceleration amplitude spectrums. The input acceleration sensor was fixed to the vibration exciter and the output acceleration sensor was placed on the end of the specimen arm. The input signal for the exciter was the chirp sinus signal in frequency range from 1 to 500Hz with amplitude 5 m/s^{-2}. The hydrodynamic exciter was controlled by displacement feedback with acceleration signal as the control signal during real-time iteration. The sampling frequency 10 kHz enables the transmissibility evaluation by using FFT analysis with 4096 points.

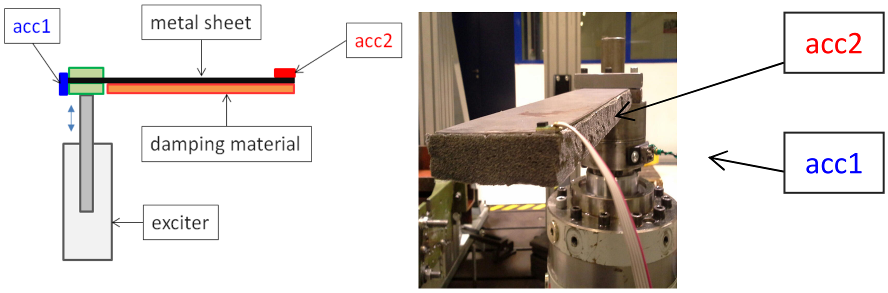
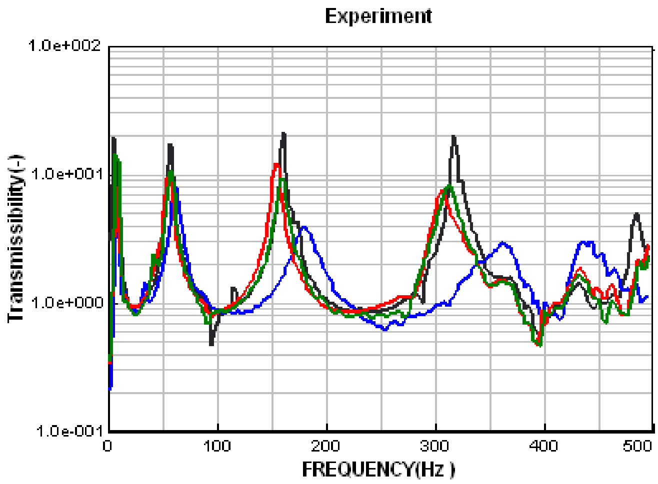


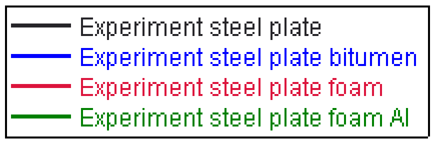
Fig. 1. Experiment configuration.

The comparison of the damping materials is described by transmissibility characteristic defined by:

$$H(f) = \frac{OUTPUT}{INPUT} = \sqrt{\frac{PSD_2(f)}{PSD_1(f)}} = \frac{acc_2(f)}{acc_1(f)} \ . \qquad (1)$$

Transmissibility characteristics of three damping materials are described in the Fig. 2.





Material	Density	Thick.	Mass
	Kg/m³	mm	g
Metal plate	7850	1	141
Foam	40	12	8,6
Foam – Al	52	16	15
Bitumen	1534	3,5	96

Fig. 2. Transmissibility and material characteristic and of used damping materials.

Simulation

The implicit frequency response simulation was computed in Virtual Performance Solution (PAM-NVH) by ESI Group. The sheet metal part model contains shell 2D elements and the material is defined by Young modulus, density and Poisson ratio.

The simulation is divided in two main steps: modal analysis and frequency response. Modal analysis is useful to get fast identification of eigenmodes and natural frequencies. This methodology is used for the validation of mechanical behavior of the structure from the experiment. The main aim is to validate the predictive models of the sheet metal and the damping material. The eigenmodes and natural frequencies of the metal sheet material are computed in linear elastic area and the results are in acceptable correlation with experiment as expected. The validation of damping behavior was done by using frequency response simulation. The results for the sheet metal only (without damping material) evince the dependency of structural damping proportional ratio on frequency (Fig. 3). It is necessary to specify the frequency depended damping of the sheet metal to get the accepted correlation with the experiment.

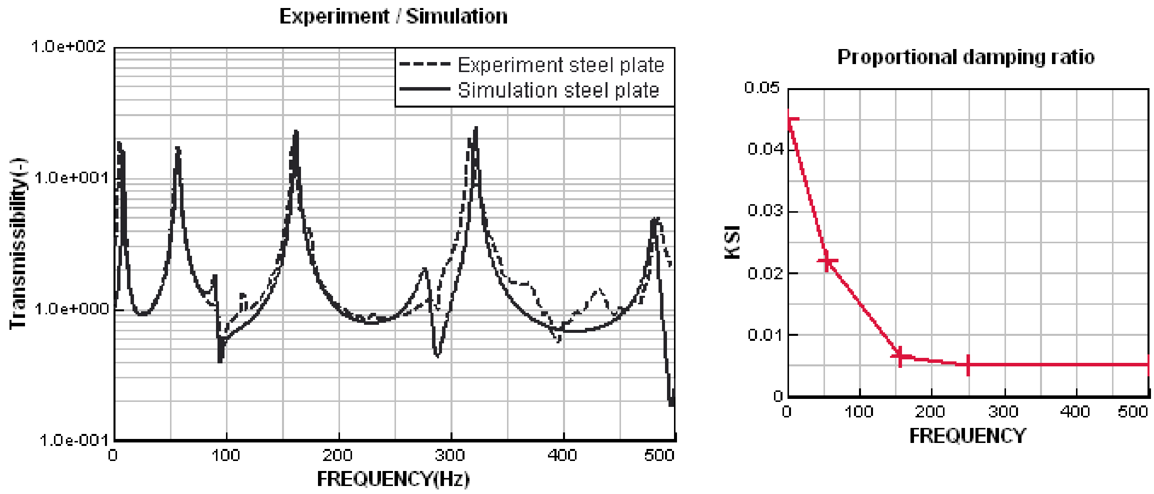


Fig. 3. Simulation results and structural damping proportional ratio dependency.

The model with damping material (foam and bitumen) contains 2D elements as the sheet metal and the damping material contains the 3D tetrahedron elements. The material model of the damping material is defined by the Bulk, Shear modulus, density and Poisson ratio. The bitumen material properties were validated by eigenmodes and natural frequencies from the modal analysis simulation results and compared with the experimental data. The damping proportional ratio was validated in frequency response simulation. The simulation results show that the damping ratio is possible to specify as the constant value through the whole frequency range. It is positive result for the predictive modeling of the damping material. Because of very small differences between experimental results of the foam with and without aluminum foil was validated only one foam material. The correlation with experimental data is acceptable (Fig. 4).

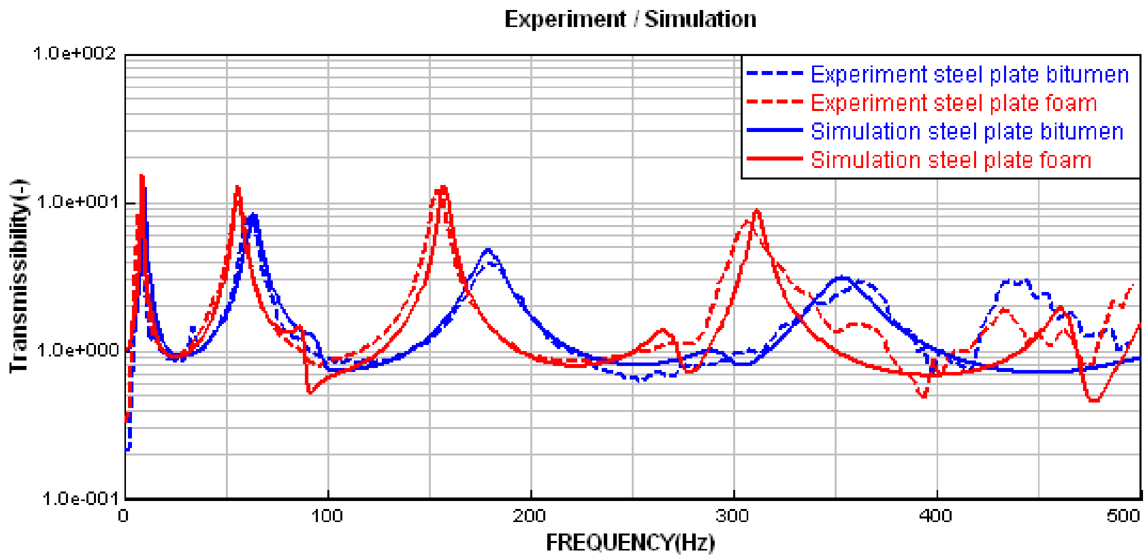


Fig. 4. Simulation results of the steel plate with the damping materials (foam and bitumen).

The differences between two mode shapes are possible to describe by MAC (Modal Assurance Criterion) which is the statistic indicator of the sensitivity and a degree of consistency. MAC between modal simulation results of the steel plate with bitumen and foam describes the correlation in lower mode shapes (1-3) and the differences between higher mode shapes (4-9).

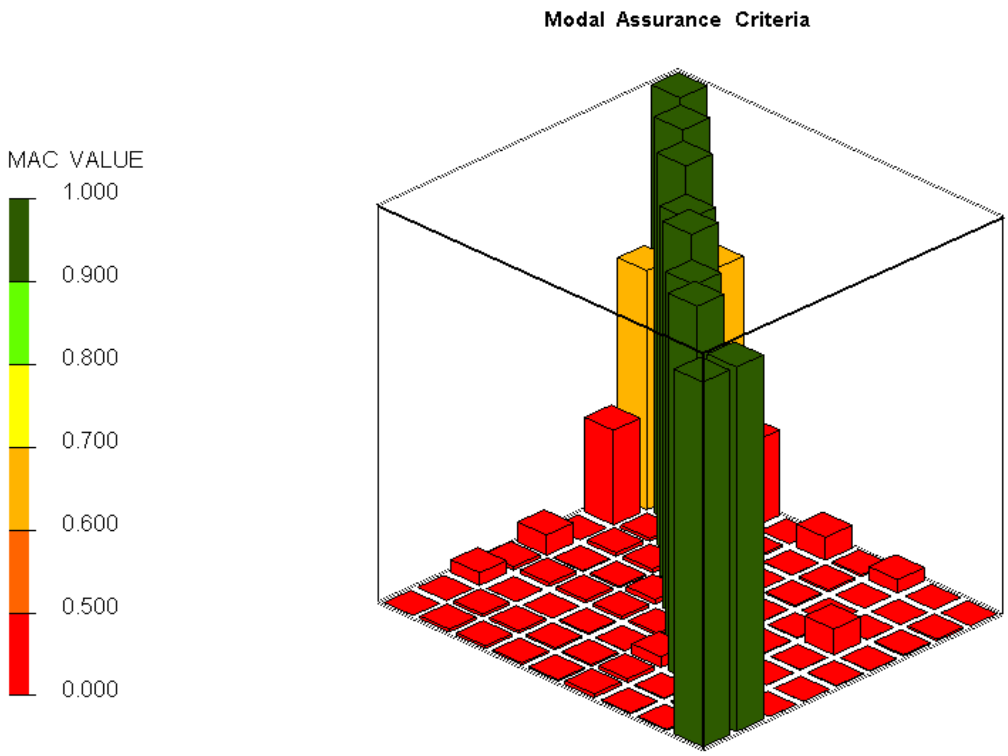


Fig. 5. MAC between simulation results of the steel plate with bitumen and foam.

Conclusions

There are significant differences in damping behavior between foam and bitumen materials. The aluminum foil glued to the foam material has only a little influence to results. The foam materials decrease the gain and shift the natural frequencies slightly. Bitumen material has stronger influence with the significant mass addition. The model of the sheet metal and damping material contains separated damping behavior of each material. Thanks to separated stiffness and damping behavior of each material is possible to use different damping material on different surfaces on the steel structure. Frequency response simulation results with both damping material are in acceptable correlation with experiment. The methodology is possible to use for damping behavior prediction of complex structures in virtual environment. The measurement was especially for damping behavior analysis.

References

[1] V. Zeman, Z. Hlaváč, Kmitání mechanických soustav, FAV ZČU v Plzni, Plzeň, 2004.

[2] D.J. Ewins, Modal Testing: Theory and Practise, Bruel & Kjaer, 1985.

[3] L. Ye, Comparison of Finite Element Method Modal Analysis of Violin Top Plate, Music Technology Area, Department of Music Research, Schulich School of Music, McGill University, Montreal, 2013.