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Characterization of the frequency-dependent properties of damping materials

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In this paper an experimental method for determining the frequency-dependent stiffness and damping properties is presented. The aim is to obtain valid input parameters for a simulation model that considers the most important effects of typical damping materials without the necessity of poroelastic material formulations, which require at least five different input parameters. These parameters are difficult and expensive to determine experimentally. Moreover, the determination procedure is not very robust and the results can easily vary [1]. Additionally, such parameters are often phenomenological without having a physical meaning. For these reasons, it is promising to use a simpler material model based on frequency-dependent stiffness and damping parameters within numerical simulations in order to be able to predict the acoustic behavior of complex systems with different damping and insulation treatments sufficiently.

1 Introduction

The comfort of modern passenger cars becomes more and more important. One main focus in the design process is on the acoustical behavior of the automobiles. The application of damping materials is one major passive treatment to improve the acoustic behavior significantly, which is additionally advantageous due to its simplicity, robustness and effectiveness [2]. Moreover, damping materials can be added if unexpected acoustical problems are found at the prototype stage. In parallel, the product development process in automobile industry progressively bases on virtual engineering methods like advanced simulation techniques [3]. Unfortunately, the modeling of damping materials within numerical vibration and acoustic analysis is very challenging [4]. The reason is that in most cases neither sufficient material data for describing the damping behavior nor a suitable knowledge about the material behavior are available. In this paper an experimental method for determining the frequency-dependent stiffness and damping properties is presented.

2 Experimental Setup

The experimental setup used for the characterization of the frequency-dependent properties of damping materials is shown in Fig. 1, where a detailed view as well as a schematic sketch of the setup is given.

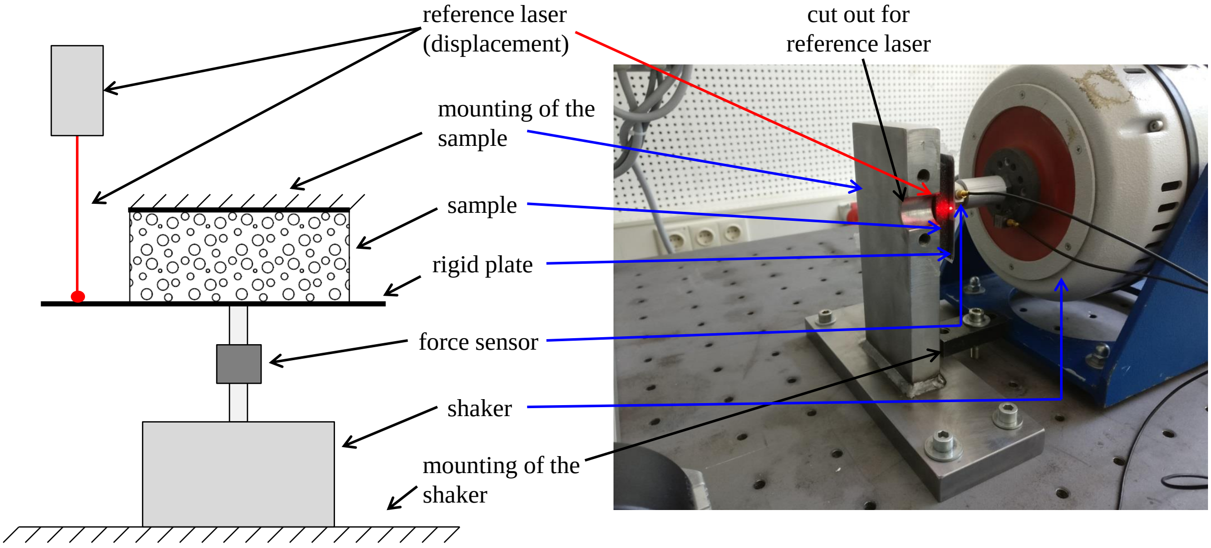

Fig. 1: Experimental setup employed to determine the frequency-dependent stiffness and damping properties of damping materials.

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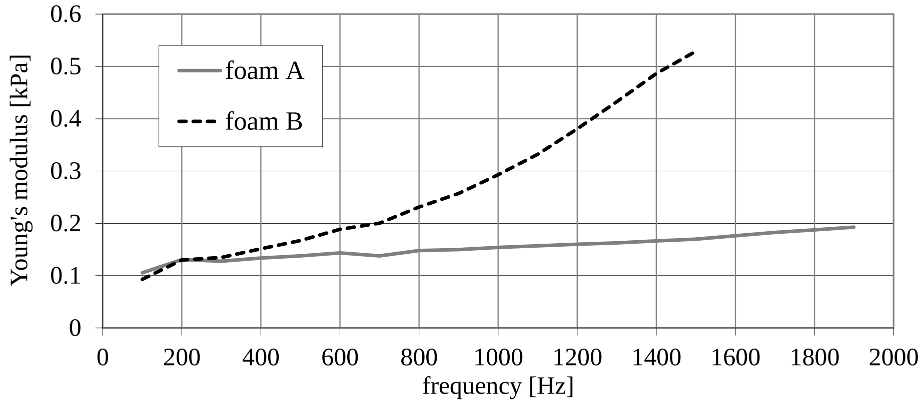

Fig. 2: Exemplary results of the experimentally determined Young's modulus of two different foam samples.

The whole setup is assumed to be rigid, except for the foam sample of interest. Hence, the system can be treated as a single degree of freedom spring-mass-damper-system. Each frequency is excited by a monofrequent harmonic force and measured separately. The measured data include the excitation force (force sensor) and the displacement (laser vibrometer). Consequently, the spring force as well as the resulting Young's modulus can be calculated under consideration of the dimensions of the foam sample and the exact mass of the overall accelerated mass. This mass is important in order to determine the inertia forces, which have to be excluded from the measured force to obtain the spring force. Moreover, the damping parameter is calculated from the hysteresis loss. These steps have to be repeated for each frequency of interest. The maximum operable frequency is limited by the power of the shaker and the intended deflection amplitude. Therefore, a lightweight set-up without violating the assumption of rigidity is used. Furthermore, it is important that the signal to noise ratio is feasible. In this context it means that the wanted spring forces may not be too small in comparison to the inertia forces, which increase with frequency. With the current setup we are able to reliably determine the material parameters up to 2 kHz. The exemplary results depicted in Fig. 2 clearly illustrate that the material parameters of such foams are frequency-dependent. However, the functional dependence can differ significantly with regard to the chosen material. We investigated several characterization methods and influence parameters and how they affect the resulting frequency-dependent material properties. Additionally, we conducted numerous numerical studies to gain a better understanding of the working principle of the whole setup and all important influence parameters. For more detailed information we refer to [5].

3 Outlook

Extensive studies are under progress to compare different experimental methods for determining the frequency-dependent stiffness and damping properties in terms of their required effort and accuracy. Exemplarily, different soft foams as typical damping materials in automotive applications are investigated. The results are evaluated by comparing numerical simulations with acoustic measurements. As reference for the validation, the measured insertion loss functions of the sound power are used. The insertion loss functions are obtained in an acoustic transmission test bench consisting of a reverberation chamber and an anechoic room, which are connected via a window in which the samples are placed. With the help of simulations the experimentally determined frequency-dependent material properties are tested in order to identify the best method to characterize damping materials from an acoustical point of view.

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