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[Reliability of experimentally determined damping values]

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Abstract

In order to increase the reliability and precision of numerical models for vibro-acoustic problems, it is often still necessary to extract and validate input parameters by performing experiments. Among the frequently needed input parameters for finite element models, damping is one of the most difficult ones to acquire. One of the reasons for those difficulties is that the boundary conditions commonly used for numerical models, e.g. free-free support or ideally clamped are not precisely feasible in an experimental setup but are mere approximations. Since the utilized type of support can affect the obtained experimental damping values, it can be necessary to pay close attention to the design of the experimental setup.

The focus of this study is set on the influence of different types of support on experimentally obtained damping values. The structural dynamical response of the used test specimen with different types of support on an impulse excitation is measured by a laser scanning vibrometer. During post-processing, the damping values are derived from the measurements and are further analysed.

Keywords: EMA, Damping, Measurement, natural frequencies, Reliability

1 INTRODUCTION

In order to improve the quality of numerical models a precise knowledge of the underlining geometrical and material properties are a necessity. In most cases the geometry of a component can be measured by either optical or tactile methods, with a precision which is for most practical application more than sufficient [12, 14, 11, 6]. The mass and in case of a homogeneous material the density of a specimen can also determined with a sufficient precision. The margin of error in the measurement of mass as well as geometry can be considered relatively small in comparison to the uncertainty in measuring the Young's modulus ($\pm 2.3\%$) or Poisson's ratio ($\pm 3.2\%$) of a homogeneous isotropic material [10]. But even these uncertainties can be considered small in comparison to the margins of errors in measuring damping. The measured damping of an assembly or component can be effected by joint damping [13, 7], the chosen type of support [1] or the surrounding fluid [2]. Furthermore experimentally obtained damping can largely depend on the settings and methods used during measurement and post-processing [9].

The focus of this paper is on the influence of boundary conditions in experimental setups on obtained damping values. As David J. Ewins mentioned in his book 'Modal Testing' one common type of suspending specimens is to approximated free-free boundary conditions with strings [5]. In this study the mounting position of such strings are slightly changed and resulting effect on the obtained damping values quantified.

2 EXPERIMENTS

2.1 Specimen and experimental setup

For the purpose of this study a plate was milled out of a solid block of aluminium AlMg4,5Mn0,7. This plate has a length of $L = 355mm$, a width of $B = 255mm$ and a height of $h = 13mm$. Along the plates edges a total of 44 equally distanced M10 threaded holes have been drilled. Along the long edges a total of 14 of those holes are placed. These were used to suspend the plate with two strings equally distanced to the plates edge. hereinafter the mounting position is described with numbers increasing form the outside to the inside of the plate. As an example '11' reference to a mounting position in the two outer holes, '22' mounting in the second holes from the outside and '77' means that the strings were attached in the two central holes. A more detailed

description of the mounting position can be found in [8].
For the excitation of the structure an automated impulse hammer from NV-Tech-Design type 'SAM1' was put into use. This allowed for a precisely controlled and repeatable impulse [3, 4]. The structural response was obtained contact-less with a Laser-Scanning-Vibrometer form Polytec type PSV500 at three points on the surface subsequently. By using an impulse hammer and a vibrometer no additional mass, stiffness or damping was added to the specimen for the purpose of excitation or measuring the response. As a result the measurements only differ in the mounting position of the suspension.

2.2 Post-Processing

In the first step the measured time data were imported into MATLAB® 2018a and transformed into the frequency domain. In the second step the data got imported into ME'SCOPE®. Here a modal analysis were performed in order to obtained the natural frequencies and damping. The results from all measurement points with the same mounting position were averaged in order to improve the reliability of the results.

$$\Delta f = \frac{f_{nn} - f_{mean}}{f_{mean}} \tag{1}$$

$$\Delta \xi = \frac{\xi_{nn} - \xi_{mean}}{\xi_{mean}} \tag{2}$$

The focus of this paper is on the modes 2, 3, 6, 7, 8, and 10 since those could be clearly identified. The influence of the different mounting position of the natural frequency and damping in displayed, as described in the equations 1 and 2, in relation to the arithmetic average of all mounting positions.

3 RESULTS

In Table 1 the averaged natural frequencies and damping values of the investigated modes are listed. It is noticeable that the obtained damping values are relatively small.

Table 1. Arithmetic average damping values and eigenfrequencies of the analysed mode-set

Mode	Damping [%]	Natural frequencies [Hz]
2	0.0092	546.2
3	0.0146	1077.5
6	0.0701	1202.8
7	0.0495	1506.4
8	0.0721	2203.0
10	0.0576	2908.4

In the left part of figure 1 the deviation of the natural frequencies for different mounting points of the suspension to the average natural frequencies are displayed. Also it seems like the eigenfrequnencies are affected by the mounting position, the observed deviations of less than $\Delta f < \pm 0.05\%$ are most likely not relevant in most practical applications.
The deviation of the damping values for different mounting points to the average value, which are plotted on the right side of figure 1 vary up to $\Delta \xi < \pm 30\%$. An interpretation of this is, that experimentally determined damping values are, at least for lightly damped structures, quite sensitive to the boundary conditions applied in the experimental setup. As a consequent it can be stated that it is unlikely to measure realistic damping values when shakers or sensors, i.e. accelerometers are attached to a lightly damped structure.

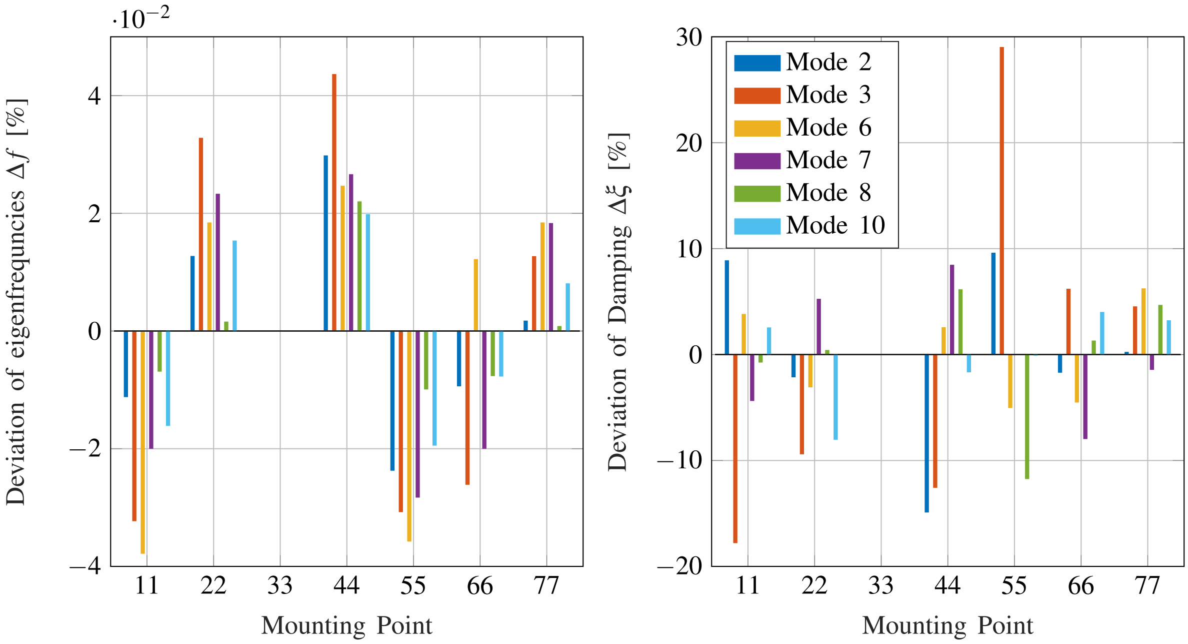

Figure 1. Difference of damping (right) and natural frequency (left) to average values

4 CONCLUSIONS and OUTLOOK

The data presented in this publication indicate, that experimentally determined damping values of light damped structures are highly sensitive to the conditions under which they have been measured. Furthermore the results shown suggest, that the natural frequencies are by far less sensitive to the boundary conditions than the obtained damping values. This has been shown on the example of an aluminium plate.

The focus of future research is set on the variance and reproducibility of experimentally obtained damping values of different mounting positions.

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