Vibration isolation experimental setup Part I: Experimental setup description

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Vibration isolation experimental setup: *The paper justifies the necessity to introduce the students to machinery vibrations theory and to the vibration isolation fundamentals. For this purpose, a mechatronic system is realized. It is built from a mechanical system with two degrees of freedom and a software system for vibration signal processing. The vibration signal processing realizes signal filtering and Fourier transformation. Through this experimental setup, the Bode plot is obtained. One can observe the resonance peak, the vibration amplification zone, and the vibration isolation zone.*

Key words: *machinery vibrations, vibration isolation teaching, experimental setup, software system, discrete Fourier transform, digital filters.*

1. Introduction

The vibration protection can be realised in two principally different ways – vibration isolation or vibration absorption. This work is focused on the vibration isolation. The future works will be dealt with vibration absorption.

The minimal model for machinery vibration investigation consist of one spatial mass and one degree of freedom (DOF), as it is shown on Fig. 1.

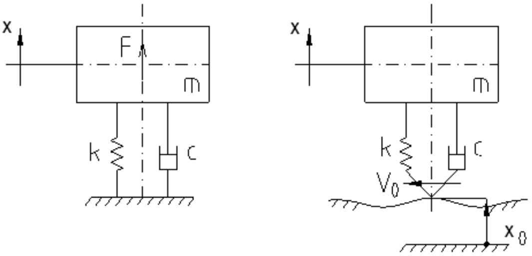


Fig. 1 One DOF models: a – force excitation; b – kinematic excitation.

For force excitation, this model is proper without any assumptions. For the kinematic excitation, it is valid when on the exciter has been applied kinematic constrains. Also, it can be acceptable if the exciter has a mass significantly greater than the mass of the object, which vibrations is investigated, for example – a vehicle traveling on a road. An experimental setup and a laboratory work for free vibrations study of a one mass model is presented in [3].

In the machinery, the most common case is when the vibrations of the elements interfere with one another. These cases are described through mechanical models with more than one degree of freedom. A theoretical investigation of a mechanical model with two degrees of freedom is presented in [4].

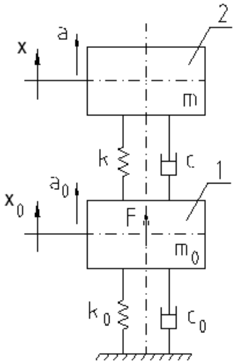


Fig. 2 Two DOF mechanical model

The experimental setup realized has two spatial masses and respectively two degrees of freedom, as it is shown on Fig. 2. The aim of this work is to investigate experimentally the vibration isolation of the second mass (position 2) from the vibration displacement of the first mass (position 1). For this, it is proper to use a Single Input Single Output (SISO) model. Also, it must be noted that this is a kinematic excitation case.

2. Description of the experimental setup

The mechanical system investigated is modelled as Single Input Single Output (SISO) system. The acceleration amplitude a_0 of the first mass (position 1 on Fig. 2) is chosen for the system input. The acceleration amplitude a of the second mass (position 2 on the Fig 2) is chosen for the system output.

Then, the transfer function of the system is [1, 2]

$$T(f) = \frac{A_0 \omega^2}{f^2 + 2\xi\omega f + \omega_n{}^2}, \quad (1)$$

where ω is the natural frequency and ξ is the damping ratio.

If one draw curve of $T(f)$ versus f, one can see haw the magnitude of steady-state response change as the frequency of the input changes. In many cases, it is more useful to express the magnitude of $T(f)$ in decibels, and to present the curve in the form of Bode plot [1]. Bode plots have several advantages: a wide range of $T(f)$ and f can be included, a number of rules can be developed to enable a designer quickly to sketch reasonable approximation of Bode plots, the transfer function can be approximated from Bode plot that have been constructed from experimental measurements. For feedback systems, the Bode plot for open-loop transfer functions provides important information about the stability of overall system [1].

The goal of this lab work is to draw the Bode magnitude plot and use it to evaluate the isolation of the second mass from first mass vibrations. For this purpose, the Bode plot is drawn from an experimentally obtained data for harmonic vibrations. In order to achieve this, the amplitudes a_0 и a of the accelerations of the masses are obtained for different values of the excitation frequency f. Then, the Bode magnitude plot is constructed according to

$$T(f) = \frac{a(f)}{a_0(f)} \quad (2)$$

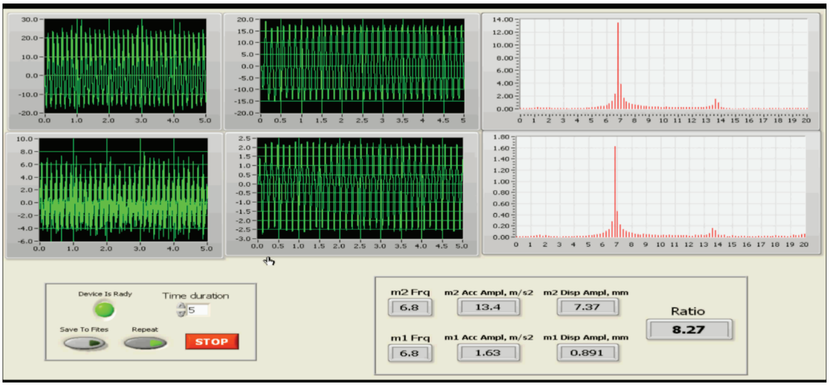
or in decibels

$$T(f) = 20log_{10}\left(\frac{a(f)}{a_0(f)}\right). \quad (3)$$

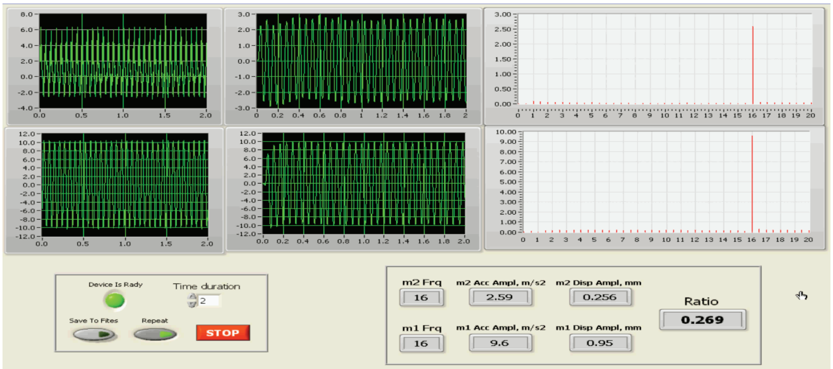
When the magnitude of the transffer function is 1, 10, 100, and 1000, respectively, the corresponding decibel gain is 1, 20, 40, and 60.

A photo of the prototype realized is shown on Fig. 3. On each of the masses is attached an accelerometer. The Vernier LabQuest device reads these accelerometers, buffers the data, and sends it to a software system developed. The software system applies a band pass filter on the vibration acceleration signal and makes a discrete-time Fourier transform to obtain the frequency spectrum. On Fig. 4, one can observe several sample time diagrams and spectrograms.

Fig. 3 The mechanical system of the experimental setup



a



b

Fig. 4. Windows from the software system developed: a – for 6.8Hz exitation frequency (resonanse); b – for 16Hz exitation frequency (vibration isolation). From left to right: the time-diagrams of the raw acceleratiojn signal; the time-diagrams of the filtered acceleration

signal; the specttrograms.The bottom row is about the first mass (pozition 1 on Fig. 2), and the top row is about the second mass (position 2 on Fig. 2)

3. Analysis of the experimentally obtained data

Table 1 shows the experimentally obtained data. On Fig. 5 and Fig. 6 are presented the corresponding plots.

On Fig. 5, one can observe that the second mass is at resonance when the excitation frequency $f_r = 6.8\,Hz$. The vibration isolation effect is present when $T(f) < 1$, and this is for $f > 9.8\,Hz$. This means that at the point $f = 9.8\,Hz$, the vibrations amplitude amplification zone ends and the vibration isolation zone begins.

To obtain the values of the system parameters in (1), it is necessary to do a theoretical investigation of the mechanical system realized.

Table 1 Data for Bode magnitude plot

f, Hz	3.0	4.0	5.0	6.0	6.2	6.4	6.6	6.8	7.0	7.2
$T(f)$	1.08	1.10	1.85	3.68	4.50	5.83	7.72	8.27	7.55	7.31
f, Hz	7.4	7.6	7.8	8	8.2	8.4	8.6	8.8	9	10
$T(f)$	5.84	3.60	3.17	2.70	2.48	1.95	1.75	1.62	1.49	0.89
f, Hz	11	12	13	15	16	17	18	19	20	–
$T(f)$	0.66	0.53	0.42	0.29	0.27	0.20	0.18	0.17	0.15	–

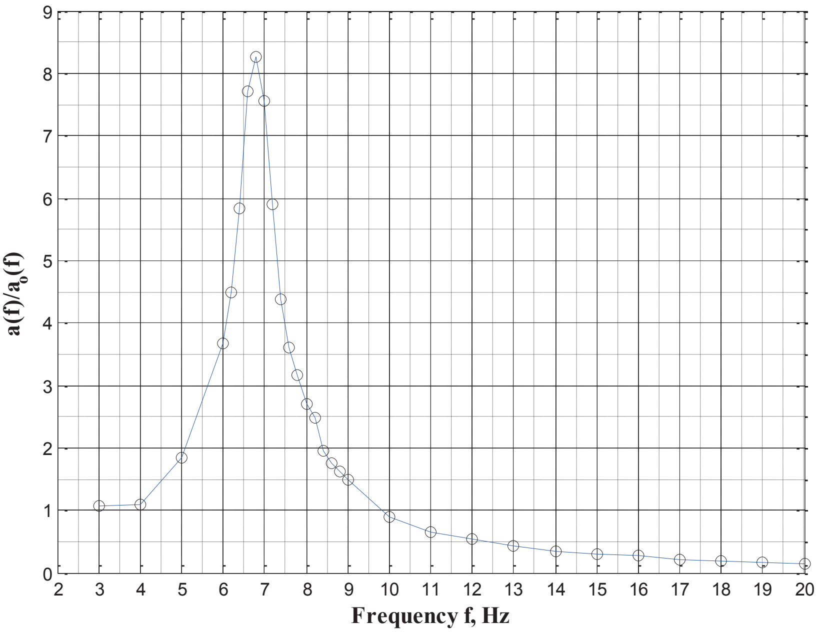


Fig. 5 Curve of T versus f, constructed from experimental measurements

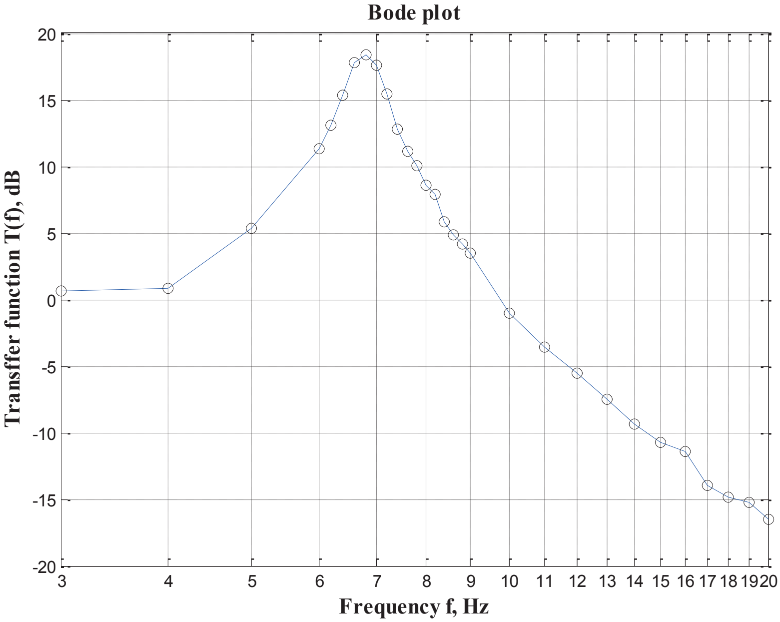


Fig. 6 Experimentally drawn Bode magnitude plot

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Докладът е рецензиран.