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TUITION OF EXPERIMENTAL DYNAMICS AT THE DEPARTMENT OF MECHANICAL ENGINEERING

VÝUKA EXPERIMENTÁLNÍ DYNAMIKY NA KATEDŘE MECHANIKY

Abstract

The paper describes, which courses from the area of experimental dynamics are given by Department of Mechanics in both bachelor and master degree studies at the Faculty of Mechanical Engineering. It concerns six courses for two study programs. In the paper, methods of tuition are described and some examples are introduced.

Abstrakt

Příspěvek popisuje, které předměty z oblasti experimentální dynamiky jsou Katedrou mechaniky vyučovány v bakalářském i magisterském studiu na Fakultě strojní. Jedná se o šest předmětů u dvou studijních oborů. V příspěvku je popsán způsob výuky a jsou zde uvedeny příklady některých úloh.

1 INTRODUCTION

Courses on experimental dynamics have long tradition at the Department of Mechanics. Two different periods can be distinguished. The previous one can be denominated as analogous - till 1989, the department was equipped entirely with analogue instruments made mainly in East Germany by RFT company. In 1990, the second period began - analogue equipment was replaced and completed with digital equipment, which enable more effective measurements, data storage and computer processing. It is possible to perform types of measurements, that were not possible to perform with analogue equipment and that's why analogue instruments are not used any more. At present, most of measurement equipment used at the Department of mechanics is a product of Brüel & Kjær company.

2 COURSES ON EXPERIMENTAL MECHANICS

At present time, courses on experimental dynamics are given both in bachelor and master degree studies, for two study programs - "Applied mechanics" and "Technical diagnostics, repairs and maintenance":

- bachelor studies
    - Applied mechanics - courses:
        - Vibration diagnostics (3rd year)
        - Basics of experimental mechanics (3rd year)

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- Technical diagnostics, repairs and maintenance - courses:
    - Technical diagnostics and reliability II (3rd year)
    - Diagnostical and operational measurements (3rd year)
- master studies - only "Applied mechanics" study program - courses:
    - Experimental modal analysis (4th year)
    - Experimental methods in mechanics (5th year)

Courses on experimental mechanics are taught in the form of lectures and laboratory seminars. Lectures are continuously updated with the knowledge gained in practise and by solving research and grant projects. The scope of laboratory seminars can be best presented on examples of performed tasks. Some of them are introduced in the next chapter. The tasks concern two main areas - vibrations and acoustics - and they involve basic tasks on vibration and acoustical measurements.

It is very important for the future mechanical engineers to be familiar with experimental mechanics, with its possibilities and limitations. It is important for them to be able to make links between experimental and computational mechanics as well. To meet this demand, links between theoretical and experimental mechanics are made with the help of common projects for two courses. Students of "Applied mechanics" study program have to elaborate one project in the 4th year, which is common for "Experimental modal analysis" and "Finite element computations", in which students verify and update their finite element models on the base of measured data.

3 EXAMPLES OF LABORATORY TASKS

3.1 The influence of weighting windows on FFT of the measured signal

This task is performed in bachelor courses. One of the problems of transforming the sampled digital time signal (originally analogue one) to frequency domain by using Fast Fourier Transform (FFT) is the finite step length Δf in the frequency domain. The actual frequencies of the signal lie mostly out of the grid defined by set of steps with the Δf interval.

On dual-channel analyzer BK2032, frequency range was set from 0 to 1600 Hz. The step $\Delta f = 2\,\mathrm{Hz}$ corresponds to this. Thus, the frequency grid consists of all even values. A vibration harmonic signal of 61 Hz was fed into channel A of the analyzer. This value fell between analyzed and displayed values 60 and 62 Hz. Without windowing, RMS value of acceleration 21,6 $m \cdot s^{-2}$ was read on the display. With Hanning weighting, value 29,1 $m \cdot s^{-2}$ was determined and with Flat Top weighting, value 35,6 $m \cdot s^{-2}$ was determined. Consequently, check of these values was performed by means of measuring time signal. Amplitude of the sinusoid was read and recalculated to RMS value - the obtained value of acceleration of vibrations was 35,8 $m \cdot s^{-2}$, which can be considered as a correct value. As the next step, the harmonic signal of 62 Hz was measured. This value coincides with one of the displayed spectral lines. The signal was measured both without windowing and using the above mentioned window types. Now, the measured values of acceleration were the same in all cases.

3.2 Measurement of acoustic power

This task is performed in master course "Experimental methods in mechanics".

The acoustic power of the source can be determined by measuring acoustic pressure according to standard ČSN ISO 3744 or by measuring acoustic intensity in points according to standard ČSN ISO 9614-1. For this task, hand-held electric drilling machine was used. Acoustic power was measured using both above mentioned methods in 1/1 octave bands and TOTAL dB(A).

During acoustic pressure measurements using sound level meter BK 2236A, the drilling machine was put on a tie-plate, bordered by a cuboid, and a measurement plane of the area 8,3 m^2

were traced out in a distance of 1 m from the cuboid's surfaces. Another measurement plane was traced out 0,3 m distant from the first one (area 21,36 m^2). Prior to the measurement itself, background acoustic pressure level in 1/1 octave bands was measured. Due to not enough space, not all points could be measured. Measurements were performed only on two side planes and at one point on the upper plane. Acoustic pressure at the pertinent points on the other planes was considered to be the same as at the points, in which it was measured. Computation in the individual 1/1 octave bands was carried out in MathCad. At first, the average acoustic pressure level at both planes was computed, then corrected value for the free acoustic field at the first plane and finally acoustic power level. From acoustic power levels at the individual frequency bands, the total acoustic power level in dB(A) was computed. Background acoustic pressure level was more than 10dB lower at all frequency bands, so it was not necessary to eliminate background noise.

During acoustic intensity measurements, the drilling machine was bordered by the same cuboid, but the measurement plane was traced out in a distance of 0,5 m from the cuboid's surfaces (area 6,41 m^2). Acoustic intensity probe and PULSE analyzer were used. For this measurement, the space in the laboratory was sufficient, but it was impossible to measure normal component of the acoustic intensity and the acoustic pressure in so many points during the time, that takes one seminar. Thus, the measurement was simplified and speeded up - only one point at each surface of measurement plane was measured and these values were taken as average values from all the measurement points. The computation in the individual frequency bands was again carried out in MathCad. The adequate number of measurement points was assessed from the non-uniform pattern of the sound field and the difference between acoustic pressure level and acoustic intensity was computed. It was found out, that the number of measurement points is sufficient and that the difference between acoustic pressure level and acoustic intensity was smaller than index of dynamic capability of the acoustic intensity measurement chain. Thus, the computation of acoustic power was finished and the total acoustic power level in dB(A) was computed. To determine the acoustic power, acoustic intensity measurements are more precise than acoustic pressure measurements. Also, less requirements are put on space and acoustic properties of the room. But, it is much more time consuming and equipment costs are higher.

Comparison of the two methods is on the Fig. 1.

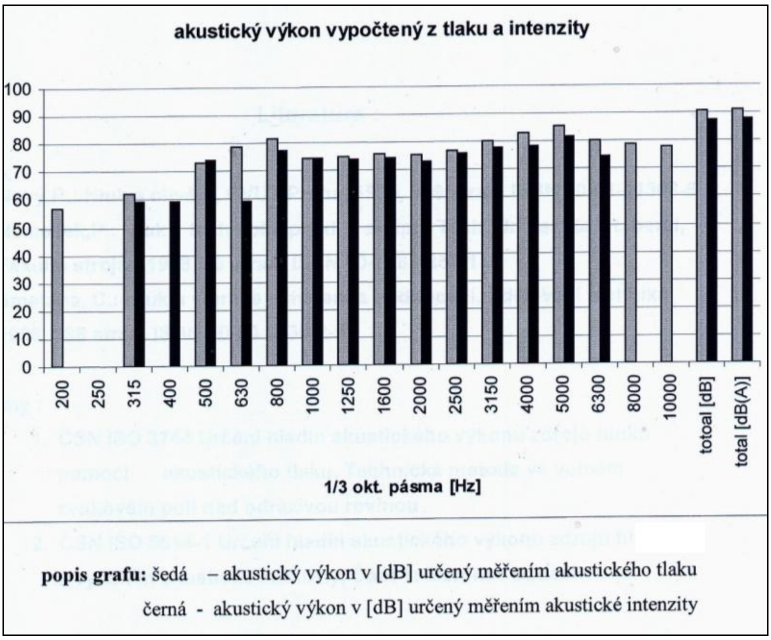

Fig. 1 Comparison of acoustic pressure and acoustic intensity measurements

3.3 Determining modal parameters

In this chapter, one of the common projects for two courses - "Experimental modal analysis" and "Finite element computations"- is introduced. Each student obtains some structure and he/she has to make a finite element model of this structure and perform computational modal analysis. Simultaneously, he/she creates so called wired model, which is used for modal test. During modal test, the structure is excited with the help of modal hammer or with the help of dynamic exciter and the excitation force is measured. At the same time, vibration responses are measured at the individual points of the wired model. This way, matrix of frequency response functions is obtained. Special software is then used for extracting modal parameters from the measured data. Each mode is characterized by three modal parameters - eigenfrequency, modal damping and modal shape.

Performing these two steps - computational and experimental modal analysis - two sets of modal parameters are obtained. Students have to compare them, identify discrepancies and, finally, update the FEM model to be in concordance with the experimental results. An example of this comparison is show at the Fig. 2.

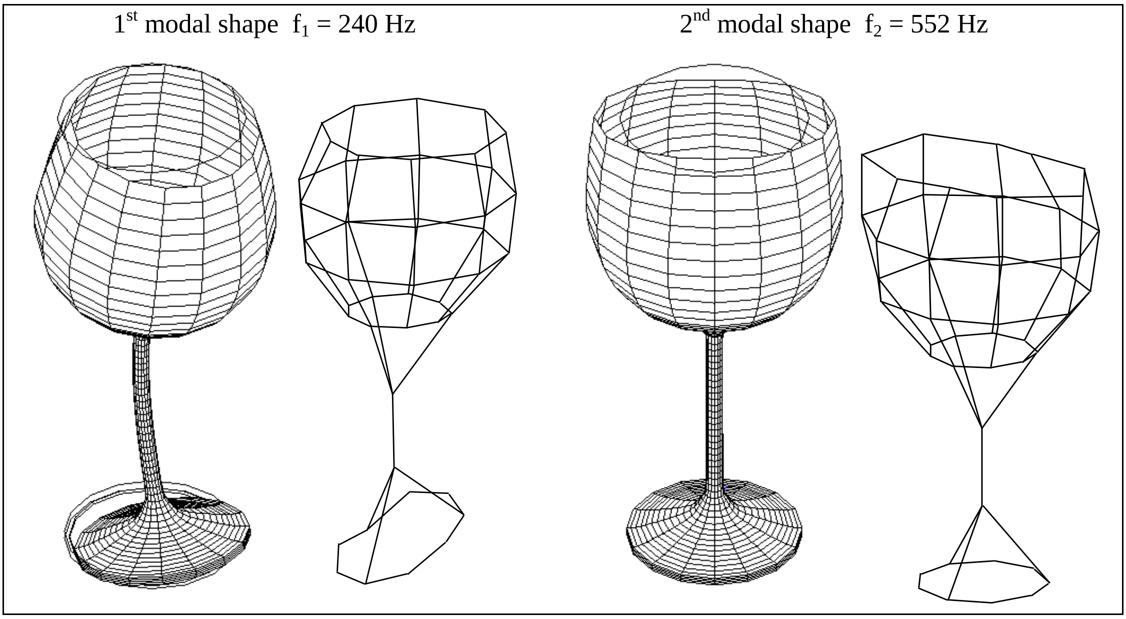

Fig. 1 Comparison of computational and experimental modal shapes

At the end of semester, we have a common session, where students present their results and discuss about problems they had to solve in their projects.

4 CONCLUSIONS

Students of the study program "Applied mechanics" would get a very good background both in theoretical and experimental mechanics and in links between these two areas during their studies. Emphasis is posed on good understanding and practical skills. Also, students are encouraged to present their projects and to discuss about the results, that sometimes might be different from what is expected. The main aim of the education is to produce graduate students, that are familiar with large number of both theoretical and practical methods used in mechanical engineering.

Reviewer: prof. MSc. Jiří LENERT, CSc., VŠB - Technical University of Ostrava