NUMERICAL INVESTIGATIONS OF THE NATURAL FREQUENCIES AND MODE SHAPES OF THE FREE SPATIAL VIBRATIONS OF A WOOD SHAPER AND ITS SPINDLE

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Abstract

This paper presents the results of the numerical investigation of the natural frequencies and mode shapes of the free spatial vibrations of a wood shaper and its spindle. The study is based on a specific mechanical - mathematical model, developed by the authors, which allows the study of vibrations of this type of machinery. In this model a wood shaper and its spindle are regarded as rigid bodies, which are connected by elastic elements with each other and with the motionless floor. This study renders an account the mass, inertia, and elastic properties and geometric parameters of the machine. The results of the numerical investigations are presented. They are obtained with modern software and by using parameters of a particular machine.
The calculated natural frequencies are necessary for the definition of the resonant modes. The exact determination of these regimes is important in connection with the implementation of adequate measures to ensure their control. The results are applicable to the formation of specific, reasonable recommendations during the operation of the concerned machinery. These recommendations are targeted at the improving the reliability of the investigated machines, and at the same time they are targeted at the accuracy and quality of production of wood shapers.

Key words: *wood shapers, modeling, natural frequencies and mode shapes*

INTRODUCTION

The vibration characteristics of the wood shapers as well as of any mechanical vibration system depend on their natural vibration frequencies. It is known that when the frequencies of the external influences, which cause vibrations, are equal to a frequency of their natural frequencies, the phenomenon “resonance” appears. Resonance regimes can lead to significant increase of vibration amplitudes and this is associated with a number of adverse consequences for both the machine and the production. Significant amplitudes of the vibrations change the normal work of the machine, thereby violating the accuracy and quality of the finished products [5], [7]. Additional stresses, associated with the increase in the amplitude of vibration, in some cases may reach value, at which one of its elements may be damaged or even destroyed [3], [6].

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All this requires making a preliminary evaluation of the risk of resonance at the design and the dimensioning of wood shapers. Their natural frequencies are necessary to be examined for this purpose [1], [2]. If the danger of resonance is presented, founded recommendations for changes in the elements of the construction have to be made

Therefore the definition of the natural frequencies and mode shapes is an indispensable stage in the study of vibration behavior of wood shapers. It is necessary for pinpointing areas of the resonance regimes.

The kind of wood shapers with lower placement of the spindle that is commonly used in practice in the forestry industry [4], [5] is examined in the proposed study. Analysis of their construction shows the strong influence of the work spindle on the functioning of the whole machine.

The aim of this study is conducting numerical investigations of free spatial vibrations of the wood shapers with lower placement of the spindle by defining and illustrating its natural frequencies and mode shapes. The investigations are made on the basis of the developed by the authors a specific mechanic - mathematical model for studying the vibrations of this type of wood shapers. The model is presented in the previous part of this work. The model renders in account the construction's characteristics of this class of wood shapers. The wood shaper and its spindle are regarded as rigid bodies, which are connected by elastic elements with each other and with the motionless floor. These elastic elements are four vibration isolators between the machine and the floor, and the two bearing units of the spindle. The parameters of a real wood shaper are used in the calculations.

The developed model is shown in Fig. 1.

The following symbols are used:

m_1, m_2 – mass of the wood shaper and its spindle;

$\mathbf{I}_1, \mathbf{I}_2$ – inertia moment tensors of the wood shaper and its spindle;

$c_{x1i}, c_{y1i}, c_{z1i}$, $i = 1, 2, 3, 4$– elastic coefficients of the vibroisolators between the machine and the floor;

$c_{x2i}, c_{y2i}, c_{z2i}$, $i = 5, 6$– elastic coefficients between the machine and the spindle.

The vector of the generalized coordinates is (Fig. 3).

$$\mathbf{q} = \left[x_1 \; y_1 \; z_1 \; \theta_{x1} \; \theta_{y1} \; \theta_{z1} \; x_2 \; y_2 \; z_2 \; \theta_{x_2} \; \theta_{y_2} \; \theta_{z_2} \right]^{\mathrm{T}} \tag{1}$$

The constructed system matrix differential equations are given in the first part of this work and analytical solutions are also presented. The numerical solutions in this part of the work were obtained with their help. The used parameters belong to the produced in ZDM - Plovdiv wood shaper FD-3 which is often used in practice. These parameters are presented below.

RESULTS

The two bodies and the whole machine are modeled with software Solid Works in this part of the study. These models are shown respectively in Fig. 2, Fig. 3 and Fig. 4. The mass center of the body 1 coincides with the center of the local coordinate system of the body 1 and the center of the reference coordinate system. The mass center of the body 2 coincides with the center of the local coordinate system of the body 2

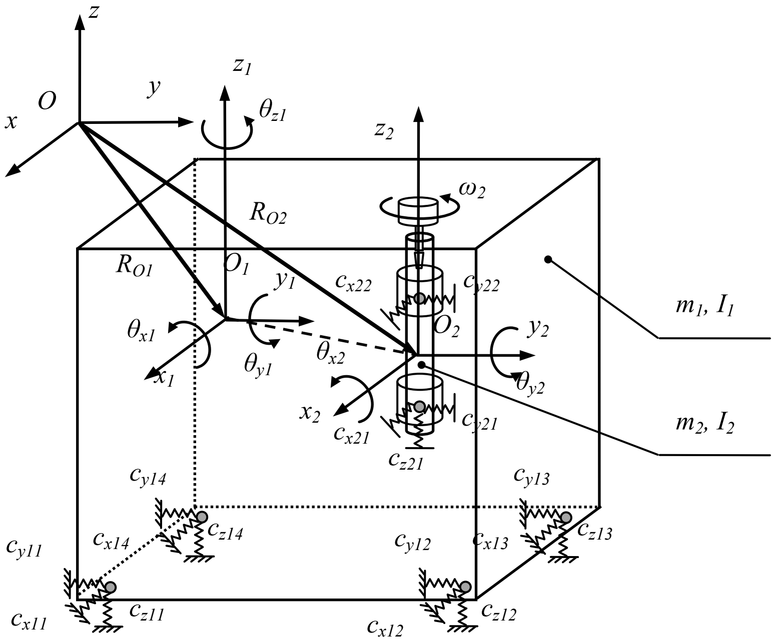

Fig. 1 Mechanic-mathematical model of the wood shaper and its spindle

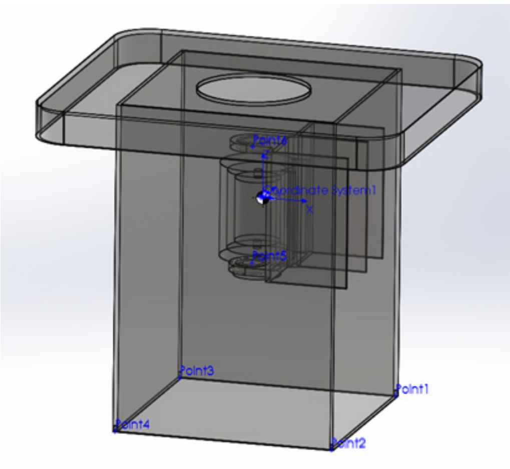

Fig. 2 – Body 1

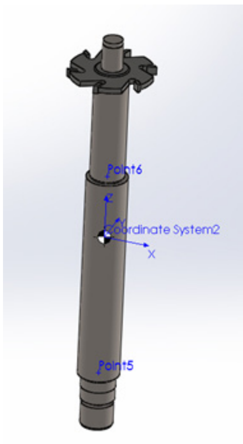

Fig. 3 – Body 2

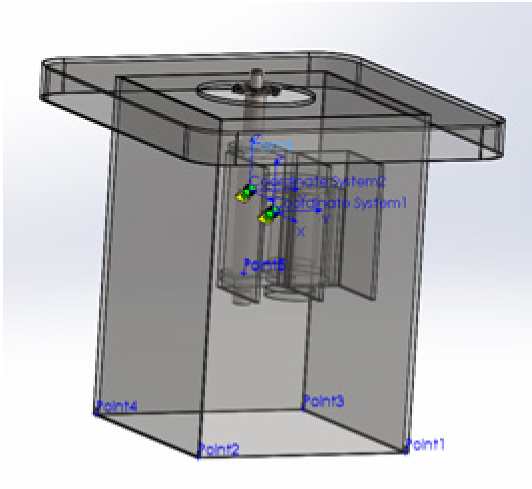

Fig. 4 – Wood shaper

The presented data below is used for calculations. It is of the used in practice milling machine FD-3 which is produced in ZDM - Plovdiv.
Mass of body 1 – m_1 = 303,43 kg; body mass 2 – m_2 = 11,12 kg. Tensor of mass inertia moments of the body 1 relative to the local coordinate system of the body 1, kg.m^2.

$$\mathbf{I_1} = \begin{bmatrix} 37,2215 & -0,1064 & -0,0566 \\ -0,1064 & 38,6641 & -0,1915 \\ -0,0566 & -0,1915 & 34,8599 \end{bmatrix}$$

Tensor of mass inertia moments of the body 2 relative to the local coordinate system of the body 2, kg.m^2.

$$\mathbf{I_2} = \begin{bmatrix} 0,2937 & 0 & 0 \\ 0 & 0,2937 & 0 \\ 0 & 0 & 0,0052 \end{bmatrix}$$

Coordinates of the pivot points of the body 1 to the center of the coordinate system of the body 1, m:

т.1	т.2	т.3	т.4
x = 0,287	x = 0,287	x = –0,303	x = –0,303
y = 0,279	y = –0,311	y = 0,279	y = –0,311
z = –0,579	z = –0,579	z = –0,579	z = –0,579

Coordinates of the pivot points of the body 2 to the center of the coordinate system of the body 1, m:

т.5 т.6

$x = -0{,}008$ $x = -0{,}008$

$y = -0{,}066$ $y = -0{,}066$

$z = -0{,}160$ $z = 0{,}151$

Coordinates of the pivot points of the body 2 to the center of the coordinate system of the body 2, m:

т.5 т.6

$x = 0$ $x = 0$

$y = 0$ $y = 0$

$z = -0{,}214$ $z = 0{,}096$

The calculations are performed by using a software product Mathematica (www.mathematica.com). The natural frequencies are 120.3 Hz; 103.2 Hz; 98.3Hz; 83.1 Hz; 67.9 Hz; 24.1 Hz; 23.8 Hz; 16.0 Hz; 13.3 Hz 6.02 Hz 6.0 Hz; 0 Hz . They are shown in the table on the right of fig. 7.
Fig. 5 graphically illustrates the calculated natural frequencies [Hz] and mode shapes of free spatial vibrations of the studied mechanical system.

CONCLUSION

The natural frequencies and mode shapes of the free spatial vibrations of a wood shaper and its spindle are calculated and illustrated in the presented study. The study is done numerically by using modern software. Calculations are made on the basis of developed specific mechanic - mathematical model for studying the vibration of the class of wood shapers. The advantages of this model are consideration of the typical characteristics in the construction of this class of wood shapers and also the ability to analyze the vibration behavior of this system. The results of the study allow based recommendations for changing the parameters of certain elements of the construction, and as a result unacceptable resonant regimes can be avoided. In a conclusion, increasing of the reliability of the machine, raising the accuracy and quality of processing of the products are the main purpose of this study.

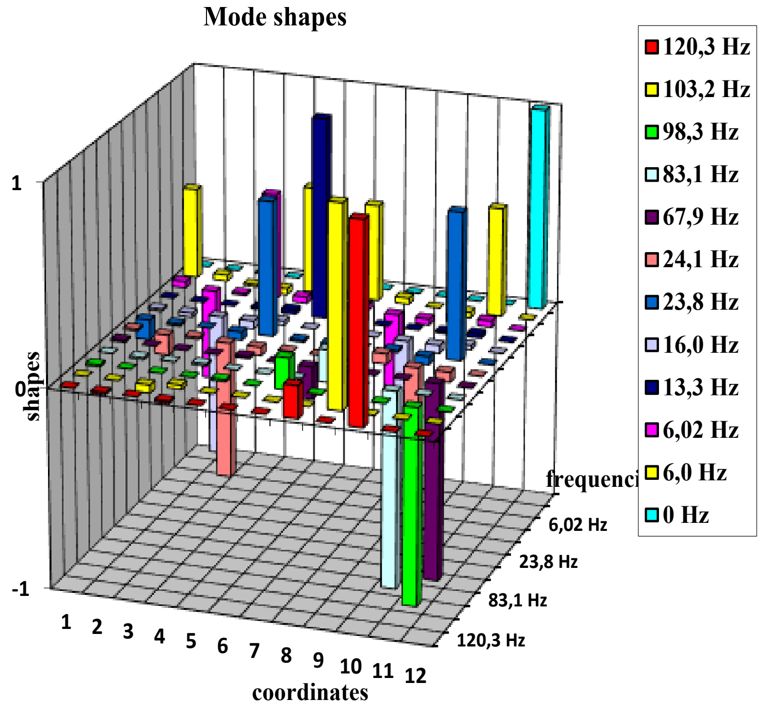

Fig. 5

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