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INFLUENCE OF THE WEARING OF THE SAW UNIT ELEMENTS OF THE WOOD SHAPER ON THE SYSTEM VIBRATION

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ABSTRACT

The article deals with the issue of vibration of lower one-spindle milling cutter. There are analyzed the causes of vibrations origin and their influence on the process of wood working. A particular attention is paid to the dependence of vibrations on the machine wear. A complete numerical model of vibration detection including a description of input variables is applied on a universal wood formating machine with a spindle in a lower position on the FD-3. The model is applied under the alternative without damping as well as under forced torcional vibrations which were caused by wear of the woodforming machine after long-term use, especially for the rotor of the electric motor, the pulley mounted on the motor shaft, the pulley mounted on the spindle and the cutting tool.

At the end, there are summarized the influences of forced torsional vibrations caused by the wear of the wood working machine FD-3 and their practical effects on the quality of the worked surface.

Key words: wood shapers, modeling, torsional vibrations.

INTRODUCTION

The wearing and the change of the parameters of the cutting mechanism's elements are one of the main reasons for the impaired accuracy and quality of the production of the wood shapers (BARCIK *et al*. 2009, KMINIAK *et al*. 2016, NEMEC *et al*. 2017). The belt drive that is included in this mechanism is its most vulnerable part and often leads to problems (WITTENBURG 1977). The faults of the electric motor, resulting from the inevitable deviation from the correct stator shape and rotor imbalance, are another problem in practice (STEVENS 2007). Intense torsional vibrations are formed as a result of the wearing and the change of the parameters of the cutting mechanism elements. The variable load from the cutting tool of the wood shaper has a significant impact on the characteristics of the torsional vibrations, (BARCÍK *et al*. 2011, BELJO *et al*. 2001, GENCHEV, OBRESHKOV 1998, GRIGOROV 1985).

Principally, the investigation of the causes for origin and increase of the torsional vibration of the wood shapers requires understanding the essence of the dynamic processes in them when the machine works (COUTINHO 2001). It is necessary to conduct purposeful studies in which the machine can be considered as a mechanical vibrating system with known characteristics of its individual elements (AMIROUCHE 2006, ORLOWSKI 2007).

Performing experiments with machines in real-work conditions is usually preceded by numerical research with using a pre-developed model and modern computing technique (VUKOV *et al*. 2016, SHABANA 2013, STEVENS 2007). The advantages of this approach are unquestionable. A wide range of operating modes and machine technical states is possible to simulate and explore. The analysis of the obtained results greatly facilitates and makes doing the next experiments with the machine in real conditions easier.

The aim of the present work is to investigate numerically and in real conditions the influence of the wearing and the change of the parameters of the cutting mechanism of a wood shaper machine on the accuracy and quality of the production. This aim requires providing some numerical investigations of the torsional vibrations of this mechanism. The free damping vibrations and the forced vibrations of the mechanism are examined under two different technical states of its elements. Analogous experiments in real conditions are then carried out.

EXPERIMENTS

Numerical investigations are conducted by the data of a commonly used in practice universal wood shaper machine with a lower spindle position (VUKOV *et al.* 2016). This wood shaper machine is a model FD-3 and is produced in the ZDM – Plovdiv. It is shown in Fig. 1.

Fig. 1. Wood shaper – general view.

The numerical investigations of the torsional vibrations of the saw unit are carried out in order to study the vibration behavior of this mechanism in wearing and change of the parameters of its elements. The saw mechanism which is at the beginning of its operation is modelled in the first investigation. The belt drive has a new belt and belt pulleys and all the components are in good condition. The free damping vibrations are studied first. A modern engineering program product is used. The necessary data for the study of the machine described above is given in Table 1.

The second investigation is a cutting mechanism which has passed a significant part of its exploitation resource but is still in serviceability. It is assumed that the belt drive has elastic and damping parameters which are degraded by continuous but not beyond the permissible work. This leads to a change in the respective coefficients of elasticity and damping. The corrected values of these coefficients are shown in the following Table 2.

The confirmation and acceptation of the conclusions from the numerical investigations requires carrying out investigations on a machine operating in real production conditions. A universal wood shaper with lower spindle model “FD – 3” is used for purpose of the studies. This machine is made in ZDM – Plovdiv. An examination of the geometry and work precision of the machine is done before each experiment.

Tab. 1 – Data 1

J_1 – inertia moment of the electric motor's rotor (kg·m^2)	0,0102
J_2 – inertia moment of the belt puller *2* (kg·m^2)	0,0740
J_3 – inertia moment of the belt puller *3* (kg·m^2)	0,0060
J_4 – inertia moment of the shaper saw	0,0141
c_1 – stiffness of the electric motor's shaft (Nm/rad)	19938, 6·
c_3 – stiffness of the spindle (Nm/rad)	64434,6
c_{23} – stiffness of the belt (N/m)	4,5.·10^5
c_{32} – stiffness of the belt (N/m)	4,5.·10^5
b_1 – damping coefficient of the electric motor's shaft (Nms/rad)	5
b_3 – damping coefficient of the spindle (Nms/rad)	5
b_{23} – damping coefficient of the belt (Ns/m)	2
b_{32} – damping coefficient of the belt (Ns/m)	2
d_1 – diameter of the electric motor's shaft (mm)	28
d_3 – diameter of the spindle (mm)	44
r_2 – radius of the belt puller *2* (mm)	95
r_3 – radius of the belt puller *3* (mm)	45
l_1 – distance between the belt puller *2* and the electric motor (mm)	240
l_3 – distance between the shaper saw and the belt puller *3* (mm)	460
M_1 – moment of the electric motor (N·m)	9,554
M_{11} – additional moment of the electric motor (N·m)	4
M_{12} – additional moment of the electric motor (N·m)	4
M_2 – moment of the belt puller *2* (N·m)	0,2
M_3 – moment of the belt puller *3* (N·m)	0,15
M_4 – moment of the shaper saw (N·m)	5,6
M_P – additional moment of the shaper saw (N·m)	2.8
ω_1 – frequency of rotation (s^{-1})	314,16
ω_4 – frequency of rotation of the shaper saw (s^{-1})	628,32

Tab. 2 – Data 2

c_{23} – stiffness of the belt (N/m)	5,5.·10^5
c_{32} – stiffness of the belt (N/m)	5,5.·10^5
b_{23} – damping coefficient of the belt (Ns/m)	1,5
b_{32} – damping coefficient of the belt (Ns/m)	1,5

The good conditions of the assembly correctness of the belt pullers and of the adjustment of the used belts are checked up carefully. The tests are done with specializing device Optibelt (Laser Pointer II and TT –3) – Germany. Specimens of black pine and beech prepared in advance are processed. Making specimens demands setting their location surface preliminary and then the bars' thickness is processed on a thicknessing machine.

A necessary condition of the experiment is at least 30-minute work of the wood shaper before starting of the examinations. In this way the reaching of the normal work temperature for all machine's elements is guaranteed. The separated investigations are carried out with preliminary determined and fixed feeding speed and frequencies of rotation of the shaper's spindle. The thickness of the removal layer is 12 mm. After the milling, the specimens are prepared for next investigations of their surface characteristics (Fig. 2).

Fig. 2 Specimens prepared for next investigations.

RESULTS AND DISSCUSION

Fig. 3 shows the graphs illustrating the free damping vibrations of the rotor of the electric motor q_1, of the belt pulley fastened to the shaft of the motor q_2, of the belt pulley fastened to the spindle q_3, of the cutting tool q_4.

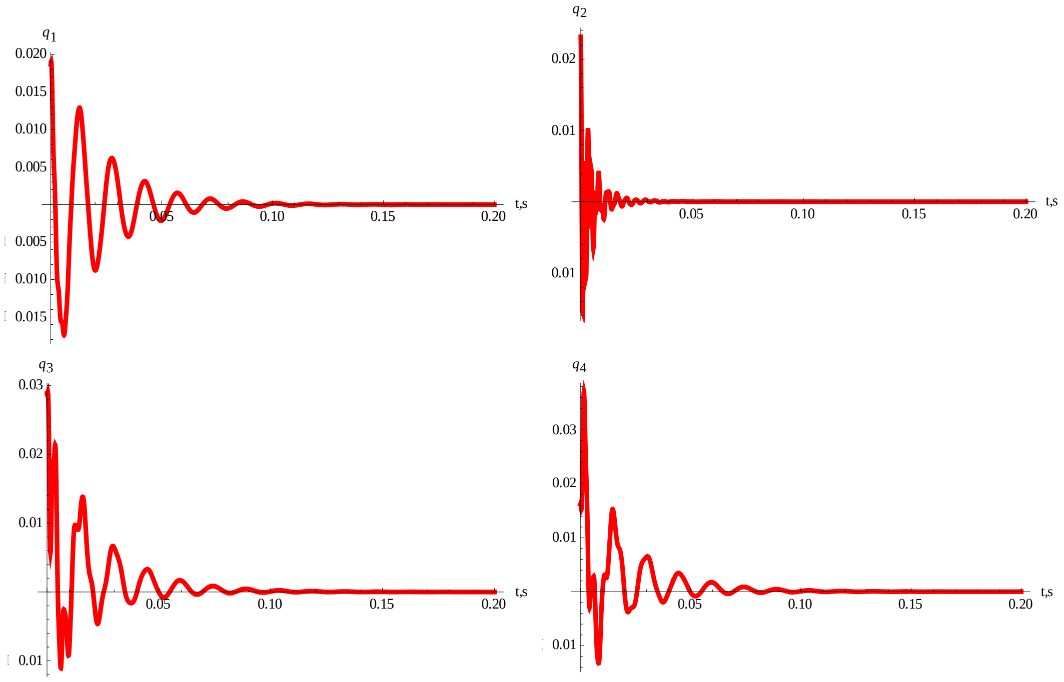

Fig. 3 Free damping vibrations – test 1.

The forced torsional vibrations of the cutting mechanism are investigated then. The variable moments from the drive motor and from the cutting tool are rendered in account. Fig. 4 shows the graphs illustrating the forced torsional vibrations of the mechanism’s elements.

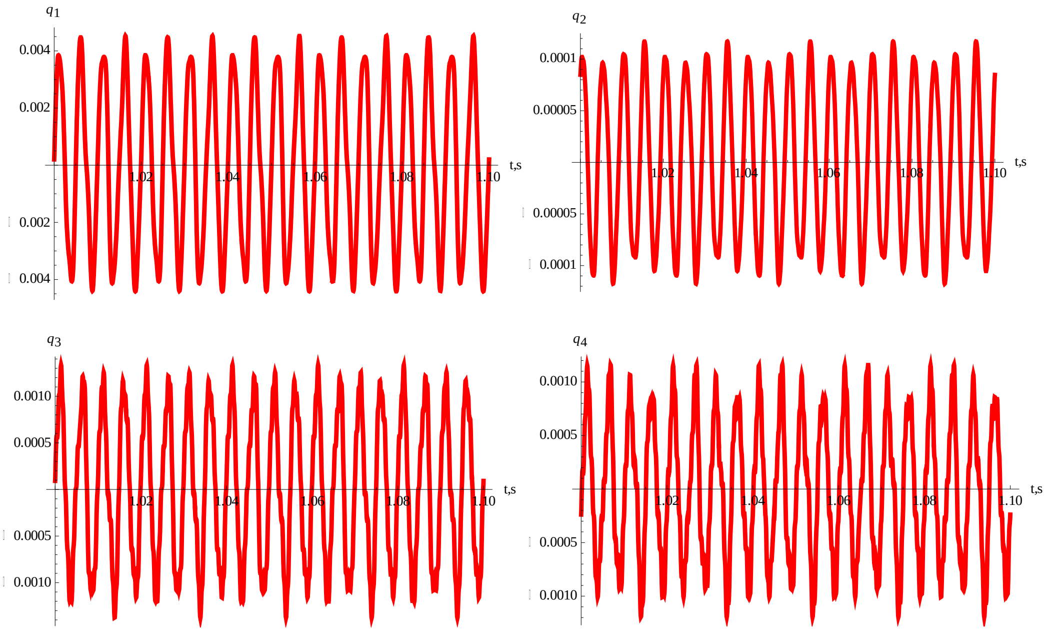

Fig. 4 Forced torsional vibrations – test 1.

Fig. 5 shows the graphs obtained with the parameters of the second investigation. They illustrating the free damping vibrations of the rotor of the electric motor q_1, of the belt pulley fastened to the shaft of the motor q_2, of the belt pulley fastened to the spindle q_3, of the cutting tool q_4.

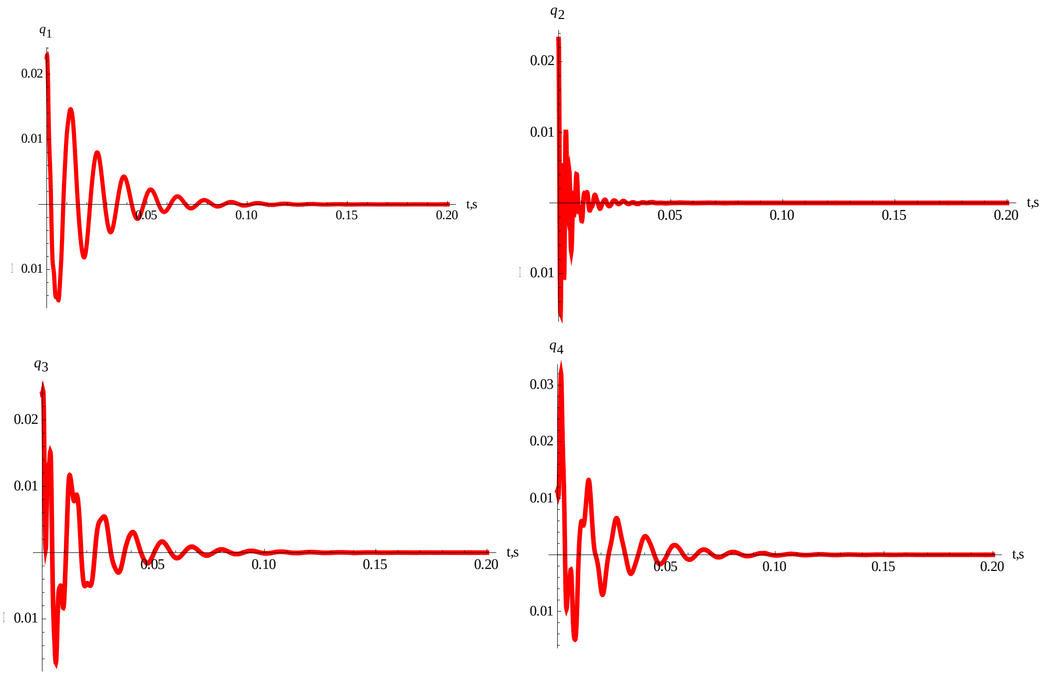

Fig. 5 Free damping vibrations – test 2.

The forced torsional vibrations of the cutting mechanism with the changed parameters are investigated then. The variable moments of the drive motor and the cutting tool are rendered in account again. Fig. 6 shows the graphs illustrating the forced torsional vibrations of the mechanism's elements.

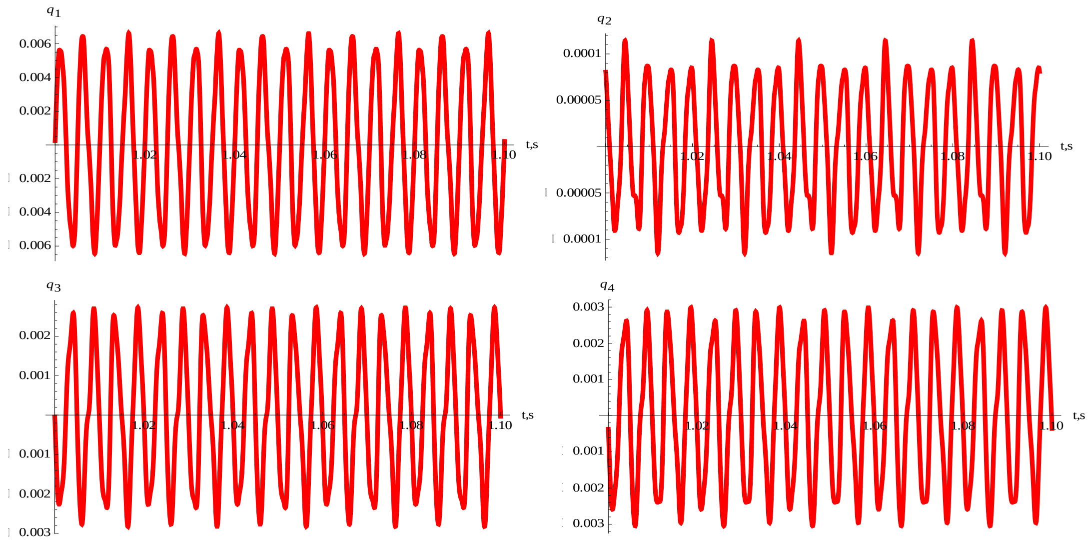

Fig. 6 Forced torsional vibrations – test 2.

The investigations show that the wearing and the change in the elastic and damping properties of the cutting mechanism's elements have influence on the formation of the torsional vibrations in it. The analysis of the obtained results leads to some conclusions. The damping of the torsional vibrations slows down when the belt drive wears and its elastic and damping properties change. The maximum amplitudes of the forced torsional vibrations increase. The graphs show that this applies most to the amplitudes of forced torsional vibrations of the electric motor's rotor and of the wood shaper's saw. This fact practically leads to the disturbing of the uniformly work of the electric motor and its faster amortization. Moreover, bigger amplitudes of the wood shaper's saw vibrations worsen the accuracy and quality of the machine's production.

CONCLUSION

This study presents the results of a research of the influence of the wearing and the change of the parameters of the saw unit of the wood shapers on the accuracy and quality of the production. The results of the numerical investigations of the torsional vibrations of this mechanism, as well as the results of the experiment under real conditions are shown and analyzed.

From the analysis of the obtained results leads to some conclusions:

- The damping of the torsional vibrations slows down when the belt drive wears and its elastic and damping properties change.
- The maximum amplitudes of the forced torsional vibrations increase.
- The graphs show that this applies most to the amplitudes of forced torsional vibrations of the electric motor's rotor and of the wood shaper's saw.

This fact practically leads to the disturbing of the uniformly work of the electric motor and its faster amortization. Moreover, bigger amplitudes of the wood shaper's saw vibrations worsen the accuracy and quality of the machine's production.

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