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INFLUENCE OF THE BELT TYPE OVER VIBRATIONS OF THE CUTTING MECHANISM IN WOODWORKING SHAPER

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Abstract

This study presents the influence of the belt type over vibrations of the cutting mechanism in a woodworking shaper. The case of the drive mechanism with the ability to use different gears is investigated. Emphasis is placed on the two widely used belts in contemporary machine building. The study is aimed at improving the reliability and efficiency of wood shaper machine to ensure the accuracy and quality of products.

Key words: *Woodworking shaper, V-belts, ribbed belts, vibration*

INTRODUCTION

Wood shapers are widespread in practice machines. Their universality allows them to be used in diverse industries in the woodworking and furniture industry. Their main use is in the manufacture of furniture, windows, doors, construction products and many other items used in everyday life. Wood shapers allow different devices to be attached to them. This increases their technological capabilities. Contemporary wood shapers should be able to work at different cutting speed. Most often the speed ranges is between 30 m/s – 60 m/s [Gochev.2005], according [Obreshkov.1997] to 90 m/s. This inevitably is associated with the machinery resources to work at different rotational speed. They are a precondition for the emergence of different cutting forces that create conditions for loads in the mechanisms which lead to errors during operation [Atanasov.2015, Vukov.2012]. Dynamic effects are constantly changing, which is a premise for permanent shifting loads in the bearings.

For driving the cutting mechanisms of wood shapers with bottom location of the working shaft most commonly V-belts and ribbed belts are used. This is the most common way to drive cutting, filing and other mechanisms in the woodworking machinery. This, undeniably is due to their advantages over other types of gears. Belt drives operate quietly and smoothly owing to the elasticity of the belt, reduce the shocks of the emerging rapid changes in load during operation of the mechanism, transmitting power over long distances [Sokolovski.2007]. Belt drives do not require special efforts to maintain. They are easy to operate; replacement of the old belt with a new one is faster and cheaper. Their simple construction means reducing costs, increasing security and durability. At the same time they enable the reduction in the level of vibration and noise.

Typical of the woodworking machines is that they operate at high cutting speeds. This requires a machine element carrying the energy of the motor to the executive parts of the machine to be able to run at high speed. Belt drives operate at high speeds – most often

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from 5 m/s to 30 m/s. There are also rapidly-operating ones which can run at speed above 60 m/s [Sokolovski.2007].
The aim of this work is the measurement and analysis of vibration speed at idle and working tread at universal wood shaper with bottom location of the working shaft. The load on the bearings is researched when using different belt drives to drive the cutting mechanism. The study is aimed at improving the reliability and efficiency of wood shaper machine to ensure the accuracy and quality of products.

MATERIAL AND METHODS

To conduct the experimental part, a universal wood shaper with bottom location of the working shaft is selected Fig.1. The cutting mechanism of the selected machine is of relatively simple construction, which helps in the more accurate execution of the experimental part. The cutting mechanism is driven by an asynchronous electric motor with a power of 3 kW and rotation frequency of 2880 min^{-1}. For the purposes of the study were designed and developed belt pulleys for V-belt with Z-section and ribbed belt PK section. During the trials, the cutting mechanism was driven by two V-belt with Z-section and one ribbed belt 3PK section.

Fig.1. *Universal wood shaper with bottom location of the working shaft*

Fig.2. *Electric motor with a pulley*

Before carrying out the practical part, it is necessary to choose the factors in which the research will be conducted. The rotation frequency used for the experiments was 6000 min^{-1}. This is one of the most commonly used frequency in milling machines. The selected rotational speed is realized by pulleys mounted on the electric motor shaft and the machine shaft. The dimensions of the pulleys depend on the technical characteristics of the electric motor Fig.2.
A cutter with diameter D = 125 mm was used Fig 3. The technical data of the cutting tool are shown in Table 1. Cutting speed, calculated to the ability of the machine to operate with rotation frequency n=6000 min^{-1} and cutting tool with diameter D=125 mm are V= 39 m/s. The cutting speed is calculated by the formula 1 [Gochev. 2005].

$$V = \pi . D . n, \text{ m./s,} \qquad (1)$$

where:
D – diameter of the cutting tool, *m*;
n – rotation frequency of the cutting tool, s^{-1}.

Fig.3. *Groove cutter*

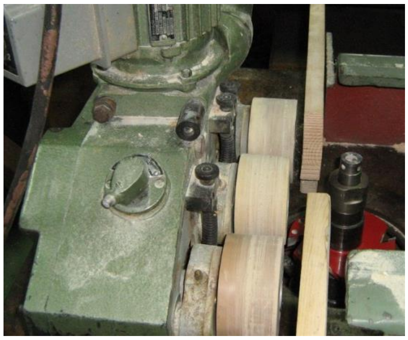


Fig.4. Roll feeder

Table 1. *Technical data of the cutting tool*

Type of instrument	***D*** **mm**	***d*** **mm**	***B*** **mm**	**α** °	**β** °	**γ** °	**z бр**	**Material of the teeth**
Groove cutter	125	30	12	16	55	19	6	HM

For the purpose of the research, a universal roller feeding mechanism is mounted to the shaper, shown in Fig.4. It consists of three feed rollers mounted in a housing. The feed speeds of the treated material, with which the experiments were made are respectively U1 = 4 m/min, U2 = 10 m/min, U3 = 16 m/min. Pine wood (*Pinus Nigra*) with thickness of the remove layer h = 12mm have been treated.

The intensity of the vibrations, whose cutting mechanism is driven by two different types of straps is assessed on the basis of the root mean square value of the vibration speed (v) $mm.s^{-1}$ (r.m.s.) measured at different working modes of the machine. The measurements have been performed at six measuring points, located on two bearing housings of the main shaft of the machine. The measurement points on each bearing housing are located mutually perpendicular radial and one axial to the main shaft of the machine Fig.5 . [BDS ISO 10816 – 2002, Gochev. 2017].

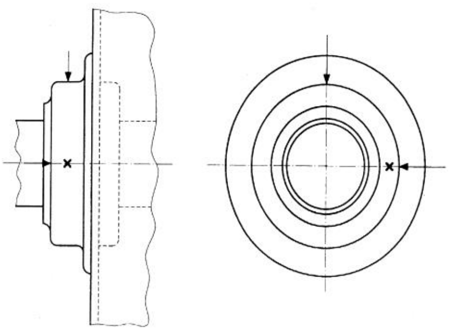


Fig.5. *Measurement points*

Fig.6. *Bruel & Kjaer Vibrotest 60*

Vibration speed is measured using a specialized device model Bruel & Kjaer Vibrotest 60 shown in **Fig.6**. The measurement points are located on the bearing housing of the machine. It significantly responds to the dynamic state. The exact vibration state measurements need to make in three mutually perpendicular directions [ISO 10816 – 2002, Gochev 2017]. Measurements are performed at idle state and during machine operation

RESULTS AND DISCUSSION

The experimental part includes idling trials and work trials in milling of pine wood (*Pinus Nigra*) specimens. The operation of the cutting mechanism was investigated when it was driven by V-belt and ribbed belt. Table.2 shows the average values of vibration speed (r.m.s) at idle state.
For the bearing housing located in proximity to the cutting tool, hereinafter referred to as "upper bearing housing", the measurement points are indicated by A: A_x – in direction parallel to the feed direction, A_y – in direction perpendicular to the feed direction and A_z axial direction.
For the bearing housing located in proximity to the driven belt pulley, hereinafter referred to as "lower bearing housing", the measurement points are indicated by B: B_x – in the direction parallel to the feed direction, B_y – in direction perpendicular to the feed direction and B_z axial direction.

Table 2. *Values of vibration speed (v) measured at idling mode with cutting tools*

Belt type	Vibration speed v, mm.s^{-1} (r.m.s)					
	Measuring points					
	A_x	A_y	A_z	B_x	B_y	B_z
2Z	2.629	3.407	2.281	1.069	2.588	2.569
3PK	2.354	2.478	2.040	0.904	1.592	2.285

Fig.7 shows the average values of vibration speed (v) mm.s^{-1} (r.m.s) at idle state close to the upper bearing housing. Fig.8 shows the average values of vibration speed (v) mm.s^{-1} (r.m.s) at idle state close to the bottom bearing.

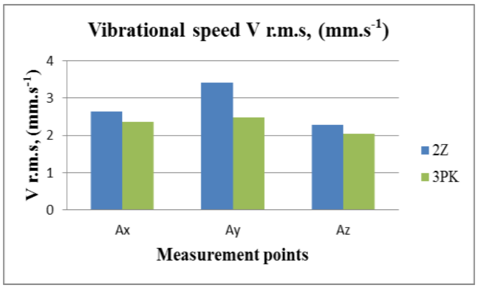


Fig.7. *Upper bearing housing vibration speed (r.m.s) at idle state*

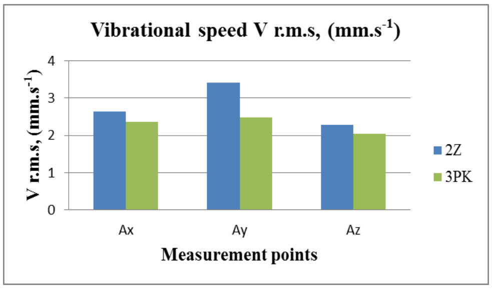


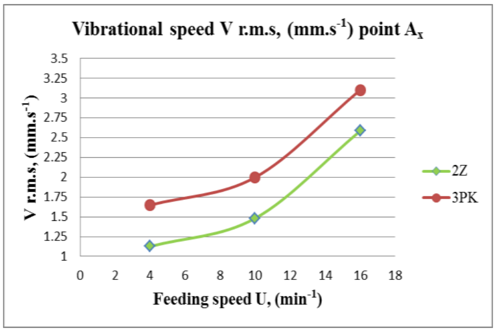
Fig. 8. *Bottom bearing housing vibration speed (r.m.s) at idle state*

Table 3 shows the average values of the measured square vibration speed (v) mm.s^{-1} (r.m.s) measured near the upper bearing housing at working mode.

Table 3. *Values of vibration speed (v) measured at a working mode close to the upper bearing*

Feed speed U, m/min	Vibration speed *v*, mm.s^{-1} (r.m.s)					
	Upper bearing housing measuring points					
	Belt type: 2Z			Belt type: 3PK		
	A_x	A_y	A_z	A_x	A_y	A_z
4	1.126	2.61	2.604	1.648	2.058	2.381
10	1.481	3.014	3.003	1.998	2.480	2.780
16	2.583	3.064	3.054	3.100	2.530	2.831

Fig.9 and **Fig.10** shows the average values of vibration speed speed (v) mm.s^{-1} (r.m.s) measured in radial direction (A_x, A_y) at working mode close to the upper bearing.



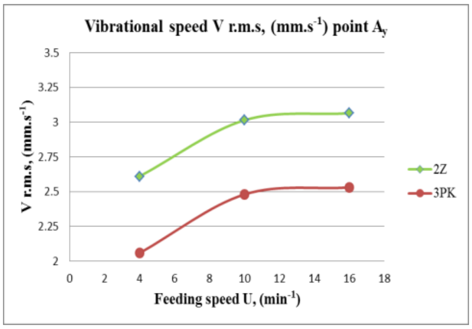


Fig. 9. *Vibration speed measured at a point Ax* **Fig. 10.** *Vibration speed measured at a point Ay*

Table 4 shows the average values of the measured square vibration speed (v) mm.s^{-1} (r.m.s) measured near the bottom bearing housing at working mode.

Table 4. *Values of vibration speed (v) measured at a working mode close to the bottom bearing*

Feed speed U, m/min	Vibration speed *v*, mm.s^{-1} (r.m.s)					
	Bottom bearing housing measuring points					
	Belt type: 2Z			Belt type: 3PK		
	B_x	B_y	B_z	B_x	B_y	B_z
4	0.709	1.508	2.951	0.549	1.062	2.705
10	1.011	1.744	3.222	0.851	1.298	2.976
16	1.164	2.368	3.276	1.004	1.922	3.030

Fig.11 and **Fig.12** shows the average values of vibration speed (v) mm.s^{-1} (r.m.s) measured in radial direction (B_x, B_y) at a working mode close to the bottom bearing. The tendency to change the vibrational speed in the axial direction at the points (Az and Bz) is the same as in the radial direction. For this reason, the vibration speed is not represented graphically.

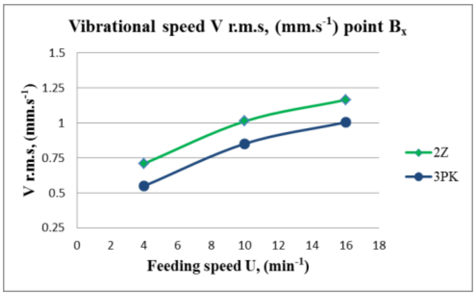


Fig. 11. *Vibration speed measured at a point Bx*

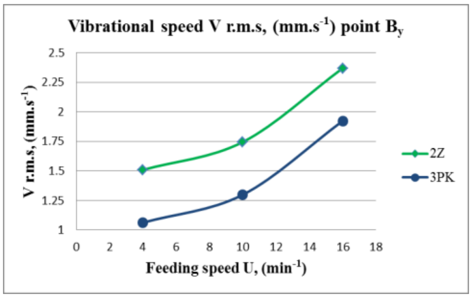


Fig. 12. *Vibration speed measured at a point By*

CONCLUSION

As a result of research and analysis of the results, the following conclusions can be made. The vibration speed (v) mm.s^{-1} (r.m.s) measured in idle is lower at the six measured points when the cutting mechanism is driven by a ribbed belt. During the working mode in the radial direction (A_x), the measured vibration speed at the three feed rates is lower with V-belts. At the other measuring points, the presented results show that machine worked better with ribbed belt PK independently from feeding speed. This gives reason to conclude that the vibration speed is lower when the cutting mechanism is driven by a ribbed belt with a PK profile. Lower vibration levels have a positive impact over the machine's overall performance, working capacity and reliability. This has a direct influence over the quality of the production.

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