INFLUENCE OF SOME TECHNOLOGICAL FACTORS OVER VIBRATION SPEED WHEN MILLING WHITE PINE DETAILS ON A UNIVERSAL WOOD SHAPER

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ABSTRACT

This study presents how some technological factors influence the vibrations of the cutting mechanism in a woodworking shaper. The experiment was carried out at different operating rotation frequencies and with cutting tools of different diameters. During the experiment, scots pine (*pinus sylvestris*) test samples were milled. Measurements were made at four points in the radial direction. Two of them are located in the upper bearing housing, and the other two are in the lower bearing housing. A universal milling machine with a lower position of the working shaft is used for the experiment. During the research, attention was paid to some technological factors such as cutting speed, feed speed of the processed material which is from $4 m.min^{-1}$ to $16 m.min^{-1}$, milling width 12 mm and thickness of removed layer 12 mm. The study is aimed at improving the reliability and efficiency of a wood shaper machine as well as ensuring the accuracy and quality of products.

Key words: Wood shapers, cutting speed, vibration speed.

INTRODUCTION

The technological modes of details processing of the milling machines are especially important. The quality of the milled parts largely depends on them, which in turn is a prerequisite for the quality of the entire product. Universal milling machines continue to be widespread in practice. They allow different types of detail processing: straight, oblique or profiled milling. We can also mount various attachments to the machine. This opens up possibilities for many other types of processing. The different types of details processing also require the machines to be able to work in different operating modes suitable for the respective technological operations. The different cutting speeds are also bound by the possibility that the machine can work with different rotation frequencies. Most often, speed ranges are between 30 m/s – 60 m/s (OBRESHKOV 1997). This is a clear prerequisite for the occurrence of different cutting forces. They load the cutting mechanism and cause forced oscillations with different magnitudes. Each processed detail of the milling machines must have a certain shape, dimensions and class of roughness to meet the tolerances laid down in the technical documentation (KMINIAK *et al.*2018, KORCOK *et al.*2018, SYDOR *et al.*2021). Vibrations are known to lead to various deviations, both in part sizes and roughness class (KOVATCHEV *et al.*2022, KOVATCHEV *et al.*2023). In order to comply with these requirements, it is necessary to choose the right technological cutting modes, correct selection and preparation of the cutting tools, as well as to check the serviceability of the machine on which the processing process will take place (ADAMCIK *et al.*2022, KOVAC *et al.*2022, SYDOR *et al.*2022, VITCHEV 2019, VITCHEV *et al.*2019, VITCHEV *et al.*2020).

The aim of the present work is to measure and analyse the vibration speed in the milling process of white pine (*pinus sylvestris*) test samples on a universal wood shaper with the bottom location of the working shaft. The object of research is the bearings load at different cutting speeds. The study is aimed at improving the reliability and efficiency of a wood shaper machine to ensure the accuracy and quality of products.

MATERIALS AND METHODS

The whole experiment in the present work was conducted on a universal wood shaper with the bottom location of the working shaft. The general view of the machine is shown in Figure 1.

The operating frequencies of the machine are 4000 min^{-1} and 6000 min^{-1}. They provide serious technological possibilities for realising different cutting speeds by using cutting tools with different diameters.

Figure 1: Wood shaper general view

The cutting mechanism of the selected machine consists of a working shaft with a bottom position, a belt drive and an electric motor. The mechanism is driven by an asynchronous electric motor with the power of 3 kW and a rotation frequency of 2880 min^{-1}. The operating frequencies of the machine are 4000 min^{-1} and 6000 min^{-1}. They provide serious technological possibilities for realising different cutting speeds by using cutting tools with different diameters. The technical data of the cutting tools are shown in Table 1.

Table 1: Technical data of the cutting tools

Type of instrument	*D* mm	*d* mm	*B* mm	α °	β °	γ °	z	Material of the teeth
Groove cutter	125	30	12	16	55	19	6	HM
Groove cutter	140	30	12	16	55	19	6	HM

The inscriptions in the table are: D – diameter of the milling cutter, d – diameter of the bore, B – milling width, α – back angle of cutting, β – angle of sharpening, γ – front angle of cutting, z – number of teeth.

The cutting speed is calculated by formula 1 (GOCHEV 2005)

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

where:

D – diameter of the cutting tool, *m*;

n –rotation frequency of the cutting tool, s^{-1}.

Table 2 shows the calculated cutting speeds at a rotation frequency of 4000 min^{-1}.

Table 2: Cutting speeds at a rotation frequency of 4000 min^{-1}

№	Rotation frequency	Diameter of the milling cutter	Cutting speed	Milling width	Thickness of removed layer
1	4000 min^{-1}	125 mm	26 m/s	12 mm	12 mm
2		140 mm	29 m/s	12 mm	12 mm

Table 3 shows the calculated cutting speeds at a rotation frequency of 6000 min^{-1}.

Table 3: Cutting speeds at a rotation frequency of 6000 min^{-1}

№	Rotation frequency	Diameter of the milling cutter	Cutting speed	Milling width	Thickness of removed layer
1	6000 min^{-1}	125 mm	39 m/s	12 mm	12 mm
2		140 mm	44 m/s	12 mm	12 mm

During the experiment scots pine (*pinus sylvestris*) test samples with cross-sectional dimensions of 50 x 50 mm and length of 600 mm were milled. The milling width is 12 mm and the thickness of the removed layer is 12 mm. A universal roller feeding mechanism is mounted on the milling machine, as shown in Figure 2. Through it, we regulate the feeding speed of the test samples. The feed speeds of the treated material with which the experiments were made are respectively U_1 = 4 m/min, U_2 = 10 m/min, U_3 = 16 m/min.

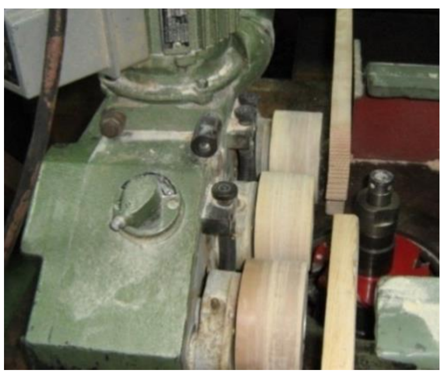

Figure 2: Roll feeder

The intensity of the vibrations is assessed on the basis of the root mean square value of the vibration speed (V mm/s (r.m.s.)). The measurements were performed at four measuring points located in the bearing house. Two of them are located near the upper bearing, next to the cutting tool. The other two are located near the lower bearing, next to the belt pulley. The measurement points are located *mutually perpendicular,* radial to the main shaft of the machine Figure 3 (ISO 10816 – 2002).

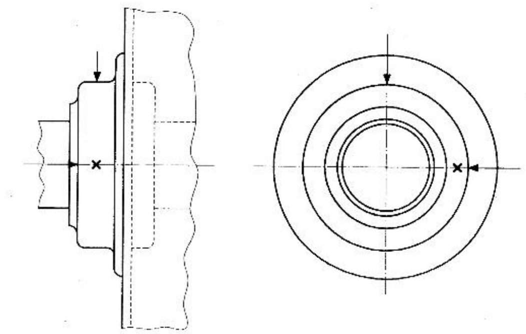

Figure 3: Measurement points

Vibration speed V mm/s (r.m.s.) is measured using a specialised device model Bruel & Kjaer Vibrotest 60 Figure 4. The sensor, which measured the intensity of vibration, is attached to the bearing house with a magnet Figure 5.

Figure 4: Bruel&KjaerVibrotest 60

Figure 5: Measuring sensor

RESULTS AND DISCUSSION

The experimental part includes work trials in milling white pine (*pinus sylvestris*) test samples. The measurement points near the upper bearing are respectively: A_x – radial direction parallel to the feed direction, A_y – radial direction perpendicular to the feed direction. The measurement points near the lower bearing are, respectively, the Bx – radial direction parallel to the feed direction and the B_y – radial direction perpendicular to the feed direction.

Figure 6 and Figure 7 show the variation of the vibration speed measured at a rotation frequency of the working shaft 4000 min^{-1} and cutting speeds of 26 m/s and 29 m/s.

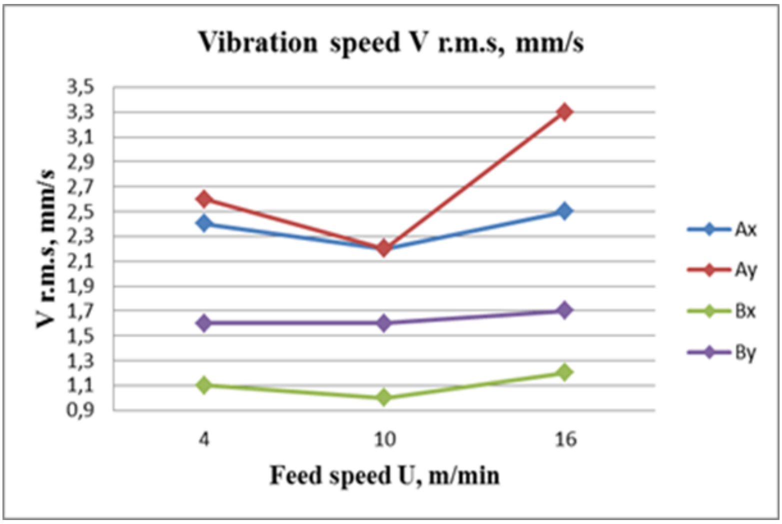

Figure 6: Vibration speed measured at a rotation frequency of 4000 min^{-1} and a milling speed of scots pine (*Pinus sylvestris*) test samples of 26 m/s

In Figure 6 it can be seen that at point A_x the vibration speed is not affected by the feed speed of the processed test samples. At point A_y, a change in the measured values of the vibration speed is observed. When the test bodies are fed at speeds U_1=4.0 m/min and U_2=10.0 m/min, a slight change is observed, but when we change the feed speed to U_3=16.0 m/min, the measured values rise to 3.3 mm/s. In the measurement points located next to the lower bearing B_x and B_y, no significant changes in the vibration speed depending on the feed speed of the test samples are read.

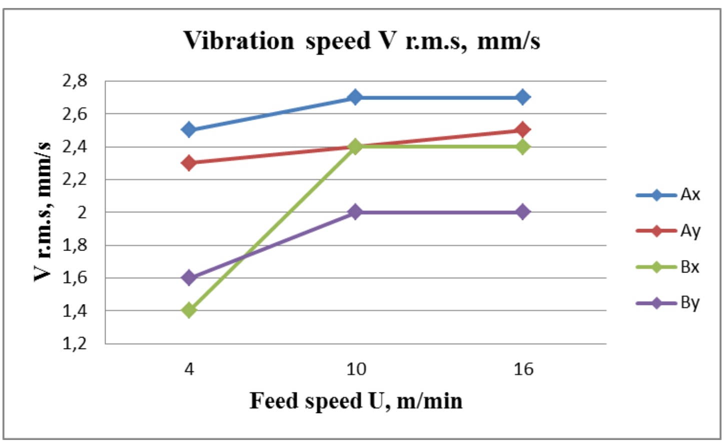

Figure 7: Vibration speed measured at a rotation frequency of 4000 min^{-1} and a milling speed of scots pine (*Pinus sylvestris*) test samples of 29 m/s

The variation of the vibration speed at a cutting speed of 29 m/s is shown in Figure 7. It can be seen that in the measuring points next to the cutting tool A_x and A_y that, there is no serious variation of vibration speed depending on the feed speed of the test samples. At point B_x the change in vibrational speed is high. Here, when the feed speed works up, the vibration increases from 1.4 mm/s to 2.4 mm/s. At point B_y we can see the same trend but there, the vibration speed increases from 1.6 mm/s to 2 mm/s.

Figure 8 and Figure 9 show the variation of the vibration speed measured at a rotation frequency of the working shaft 6000 min^{-1} and cutting speeds of 39 m/s and 44 m/s.

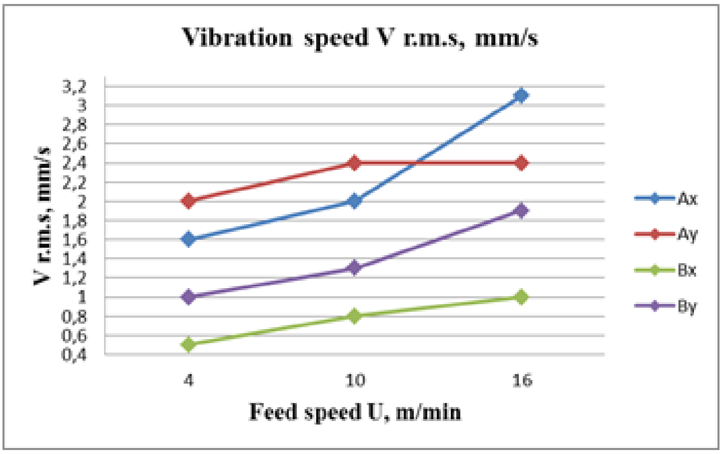

Figure 8: Vibration speed measured at a rotation frequency of 6000 min^{-1} and a milling speed of Scots pine (*Pinus sylvestris*) test samples of 39 m/s

In Fgure 8, it can be seen that in all four measurement points, when the feed speed run high, the vibration speed also increases. It is most visible at points A_x and B_x. When the feed speed of the test samples is U_3=16,0 m/min, the vibration speed at point A_x increases to 3.1 mm/s. The vibration speed increases at point B_x as well up to 1.9 mm/s. In the other two points, the increase in vibrational speed is not so large.

The variation of the vibration speed at a cutting speed of 44 m/s is shown in Figure 9. Here, in all four measurement points, when the feed speed of the test specimens increases, the vibration speed also increases. The difference in the measured values in all four points is about 0.5 mm/s for the different feed rates.

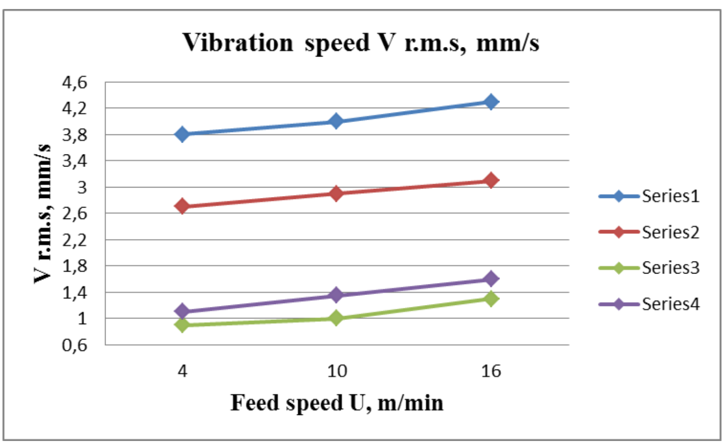

Figure 9: Vibration speed measured at a rotation frequency of 6000 min^{-1} and a milling speed of Scots pine (*Pinus sylvestris*) test samples of 44 m/s

From the conducted experiments, the following conclusions can be drawn:

- From the graphs we can see that at a rotation frequency of 4000 min^{-1} and a cutting speed of 26 m/s, the vibration speed does not always increase at each measurement point when the feed speed of the test samples increases. At the same rotation frequency and cutting speed of 29 m/s, when the feed speed increases, the vibration speed increases at all four measurement points.
- At a rotation frequency of 6000 min^{-1} for both investigated cutting speeds, the vibration speed increases at all four measurement points when the feed speed of the test samples increases.
- It would be good if the test samples were fed at lower speeds. In this way, the vibration speed is the lowest, the quality of the surfaces is the best, and the accuracy of the shape and dimensions of the parts is the closest to the technical specification (KOVATCHEV *et al.*2021, KOVATCHEV *et al.*2022, KOVATCHEV *et al.*2023).
- It is recommended to use a rotation frequency of 6000 min^{-1}. It makes it possible to realise higher cutting speeds with different diameters of the cutting tools. Research shows that there is not much difference in the measured vibration speed at 6000 min^{-1} and 4000 min^{-1} rotation frequency.

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