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THE INFLUENCE OF MILLING HEADS ON THE QUALITY OF CREATED SURFACE

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ABSTRACT

The article deals with the issue of a plain milling by using the quadripartite milling machine, in particular, the influence of method of clamping the planing blades into milling heads with hydraulic clamping and feed speed on the quality of created surface expressed as a surface roughness value. The quality of created surface is monitored on the basis of the **surface roughness value R_z, i.e. the maximum height of the profile unevenness**. The article compares **the method of fixing the planing blades in eight-blade milling head with hydraulic clamping,** which is clamped on the shaft of the quadripartite milling machine within the three levels of feed speed $\boldsymbol{v_f}$ **= 6, 15, 25 m·min^{-1}**. The comparison is made on a **tangential spruce sawn timber** with an absolute humidity of $\boldsymbol{w_a}$ **= 9÷12%**, and with a cutting speed of $\boldsymbol{v_c}$ **= 58 m·s^{-1}**.

The article observes that the quality of the surface will improve by **31 %** from the value of **R_z = 60.068 µm** with milling Hydro head without back fixation of planing blades to the value of **R_z = 45.552 µm** with milling Hydro head with back fixation of planing blade due to maintaining the tolerance of cutting diameter of circle with milling Hydro head with back fixation of planing blades when comparing both the above milling Hydro heads with and without back fixation.

Key words: norway spruce, milling head, feed speed, milled off clearance, quadripartite milling machine.

INTRODUCTION

Wood milling is a wood machining operation process of using cutters to remove material from the workpiece in the form of small splinters by using a tool with several cutting edges, i.e. by milling cutter (SVOREŇ 2006). This method of machining is chosen to achieve a smooth surface and accurate workpiece dimensions (ZHAO *et al*. 2016, KOCH 1985, PROKEŠ 1987).

A quadripartite milling machine is designed for longitudinal milling and profiling of machined parts made of wood. Design of machine allows machining of four sides of workpiece when part is passing the machine for once (LIPTÁK *et al*. 1979, SVOREŇ 2006).

Current quadripartite milling machines use 4–12 milling heads with larger diameters (160–220 mm) and higher number of blades in head. It allows to increase the feed speeds (JANDA and KMINIAK 2013, LISIČAN *et al*. 1996, LISIČAN and MÝTNY 1987).

The fixing of milling heads into the quadripartite milling machine can be classic by using a nut, or we can use the Powerlock system – by using an extensible central mandrel, or that is hydraulic fixing by using a flexible wall of milling head (milling head with hydraulic clamping). The principle of hydraulic clamping of the milling head lies in the fact that the channels and chambers built in the tool head by means of a high pressure grease press are filled with grease to increase the pressure in the channel to about 30 MPa.

The fixation of planing blades in the milling head with hydraulic clamping can be without **back fixation of planing blades,** i. e. the planing blades are fixed by a pressure bar and fastening bolts), or with **a back fixation of planing blades,** i.e. the planing blades are fixed by a pressure bar and a fastening bolt, or by a pressure bar using the Hydro clamping. According to Slovak standard STN ISO 4287, the maximum height of the profile unevenness expressed by the surface roughness value (R_z), i.e. the sum of the maximum height of the profile Z_p and the maximum depression of the profile Z_v within the basic length, is the most commonly used parameter to evaluate the quality of created surface (SANDAK and NEGRI 2005), as well as (BARCÍK and KMINIAK 2008, KETURAKIS and JUODEIKIENÉ 2007 DUBOVSKÁ 2000, ŠUSTEK 2010, ROUSEK 2004). The quality of created surface as well as the energy demand for the machining process of workpiece are dependent on the physico-mechanical properties of the material being machined as well as shape, size, sharpness and geometry of the cutting tool and the technical and technological conditions for the implementation of machining process (KMINIAK and GÁF 2015, OČKAJOVÁ *et al*. 2010, ROUSEK *et al*. 2005, DZURENDA 2008).

The objective of this paper is to judge the influence of milling heads design with hydraulic clamping on the quality of created surface expressed as a surface roughness value when milling by the quadripartite milling machine.

EXPERIMENTAL PART

Characteristics of test samples

- woody plant: **Norway spruce** (*Picea abies*),
- Sawn timber type: **tangentially**,
- humidity: $\boldsymbol{w_a}$ **= from 9 to 12%**,
- dimensions: thickness ***h* = 18 mm**, width ***w* = 105 mm,** length ***l* = 4000 mm**,
- Number of test samples: **90 pieces**

Characteristics of the machine

Experimentation – the milling was carried out by an eight-shaft quadrilateral milling machine **SK 908S** made by the company **SK Machinery - Taiwan** (**Figure 1**). The specifications of the milling machine are mentioned in **Table 1**.

Tab. 1 Specifications of quadrilateral milling machine SK 908S.

Cutting speed	58.09 m·min^{-1}
Feed speed	5–48 m·min^{-1}
Feed input	11.1 kW
Number of cylinders	8
Number of milling heads	8

Characteristics of milling heads

We used the following milling heads to conduct this experiment:

I. **Eight-blade milling head with hydraulic clamping without back fixation of planing blades** (**Figure 2**) is a milling head made from the tool steel, diameter *D* = 180 mm (As for the basic parameters of the milling head, see **Table 2**) with replaceable planing blades (from HSS 18 %W, dimensions: 35 × 3 × 130 mm).

II. **Eight-blade milling head with hydraulic clamping with back fixation of planing blades** (**Figure 3**) is a milling head made from the tool steel, diameter D = 180 mm (As for the basic parameters of the milling head, see. **Table 2**) with replaceable planing blades (from HSS 18 %W, dimensions: 35 × 3 × 130 mm). The clamping pressure of milling head on the shaft is 30 MPa. The pressure agent is the lubricating grease NH2.

Fig. 1 Quadrilateral milling machine SK 908S.

Tab. 2 Basic parameters of eight-blade milling heads.

Diameter of milling machine body	180 mm
Cutting diameter of milling machine body accross hanging blades	185 mm
Width of milling machine body	130 mm
Number of blades	8
Geometry of cutting wedge	β=55° γ=15°

Fig. 2 The milling head with hydraulic clamping without back fixation of planing blades.

Fig. 3 The milling head with hydraulic clamping with back fixation of planing blades.

The procedure for obtaining the test samples for measurement of roughness

Square-sawn timber having dimensions of 18 × 105 × 4000 mm was counter-milled by quadrilateral milling machine with the feed speed of 6, 15, 25 $m \cdot min^{-1}$ and the cutting speed of 58,09 $m \cdot s^{-1}$. After milling off 0, 2400, 4800, ..., 9600 running meters, the workpiece having dimension of 15 × 100 × 4000 mm was taken away of which the test samples were obtained on the basis of sawing scheme, see **Figure 4**.

Characteristics of the measuring equipment

The roughness of surface in test samples is measured by **Laser profilometer LPM-4** which was assembled by the company KVANT s.r.o., Bratislava (**Figure 5**).

LPM 4 uses laser triangulation profilometry. Imaging of a laser line is recorded under the angle on a digital camera. Subsequently, the profile of the object in cross section is evaluated based on the image recorded. **Figure 6** illustrates the operating principle of Laser profilometer.

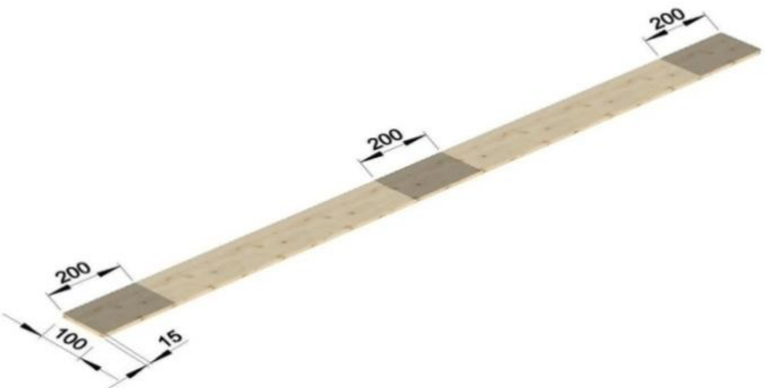

Fig. 4 Selection of samples for the measurement of surface roughness.

Fig. 5 Compact profilometer LPM.

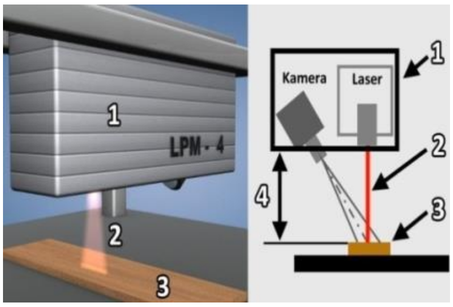

Fig. 6 Operating principle of the Laser profilometer LPM 4 (1-camera, 2-laser, 3-test sample, 4- distance between the LPM profilometer and the measured object).

The procedure for measuring the surface roughness of test samples

The Slovak Standard STN EN ISO 4287 was taken into consideration when measuring roughness. For each sample, the measurement was carried out in five tracks evenly spread across the width of the sample (i.e. 10, 30, 50, 70, 90 mm from the edge of the sample), the length of the track was 80 mm, it was oriented in the direction of feed of the workpiece in the process of milling. The roughness of surface was judged on the basis of the maximum height of the primary profile R_{z}.

RESULTS AND DISCUSSION

The roughness of spruce material when plain milling using the quadrilateral milling machine depending on the method of fixing the planing blades into the milling Hydro head, the running meters milled off (wear of cutting edge) and feed speed is illustrated in **Table 3**.

Tab. 3 Basic statistical values of the characteristic R_z, depending on the processing time and the method of clamping the planing blades in the milling Hydro head.

Type of clamping the milling head	Milled off clearance L [run. meters]	The maximum height of profile unnevenness expresed as a roughness value R_z [µm]		
		Feed speed v_f [m·min^{-1}]		
		6	15	25
hydraulic clamping	1200	58.64 ± 10.12	59.96 ± 9.18	66.54 ± 8.21
	2400	32.77 ± 8.23	45.62 ± 10.41	74.58 ± 12.15
	4800	38.22 ± 4.07	51.33 ± 8.38	77.52 ± 13.22
	7200	45.62 ± 10.30	52.72 ± 4.15	83.46 ± 10.36
	9600	52.51 ± 6.18	57.88 ± 4.43	85.09 ± 4.47
classic clamping	1200	75.04 ± 10.01	63.15 ± 3.21	75.51 ± 10.15
	2400	43.16 ± 5.23	66.25 ± 6.28	80.31 ± 10.31
	4800	54.64 ± 9.44	71.52 ± 2.68	87.37 ± 6.68
	7200	59.69 ± 5.18	78.36 ± 5.48	95.69 ± 10.02
	9600	67.81 ± 5.36	80.59 ± 4.18	110.2 ± 9.18

Three-Way Analysis of variance (ANOVA) has shown that the type of fixing the planing blades in the milling Hydro head, feed speed and milled off clearance has significantly influenced the surface roughness of spruce sawn timber, see **Table 4.**

Fisher's F test indicates that the statistical significance of the type of fixing the milling head is about 48% greater than that of the feed speed.

Tab. 4 Basic table 3 – Multivariate Analysis of Variance (MANOVA).

Source of variability	Sum of squares	Degree of feedom	Variance	Fisher´s F-test	p-value (sig. level)
Total mean	**7596415**	**1**	**7596415**	**641.89**	**0**
Milling Hydro head	**236544**	**1**	**236544**	**19.99**	**0**
Feed speed	**225635**	**2**	**112818**	**9.53**	**0**
Milled of clearance	**214523**	**3**	**1109325**	**8.52**	**0**
Milling Hydro head * Feed speed	21043	2	10522	0,89	0.413
Milling Hydro head*Milled off clearance	68405	4	17101	1.45	0.222
Feed speed*Milled off clearance	135050	8	16881	1.43	0,19
Milling Hydro head*Feed speed*Milling off clearance	73589	8	9199	0.78	0.623
Random factors	1775171	150	11834		

Figure 7 indicates dependence of the surface roughness on the feed speed for different types of fixing the planing blades in the milling Hydro head when milling with the quadrilateral milling machine.

Despite the identical parameters of milling machines (diameter, number of blades, material of blade, angle geometry of blade, blunting), the surface roughness R_z is always lower when using the milling head with hydraulic clamping with back fixation of planing blades compared with the milling head with hydraulic clamping without back fixation of planing blades. The average value of surface roughness, when using the milling head with hydraulic clamping with back fixation of planing blades, is R_z = 45.552 µm. The average value of surface roughness, when using the milling head with hydraulic clamping without back fixation of planing blades, is R_z = 60.068 µm, which represents a difference of 31 %.

When increasing the feed speed, the surface roughness increases linearly for both methods of fixation of planing blades in the milling head with hydraulic clamping. The following authors came to the same conclusion in their works: (PIVOLUSKOVÁ 2008, GÁBORÍK and ŽITNÝ 2010). They also confirmed that the feed speed influences the quality of surface of the machined material. When changing the feed speed from 6 m·min^{-1} to 15 m·min^{-1}, the R_z increases by 19 % and from 15 m·min^{-1} to 25 m·min^{-1}, the R_z value increases by 24 % in the case of using the milling head with hydraulic clamping without back fixation of planing blades.

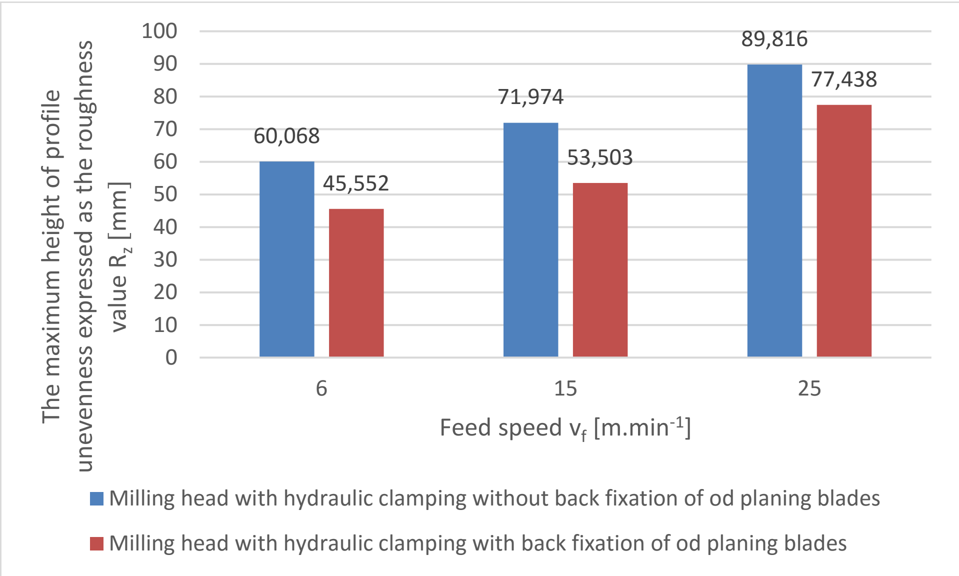

Fig. 7 The dependence of surface roughness R_z [µm] on the feed speed of wood material when milling v_f [m·min^{-1}].

When changing the feed speed from 6 m.min^{-1} to 15 m·min^{-1}, the R_z value increases by 17 % and from 15 m·min^{-1} to 25 m·min^{-1}, the R_z value increases by 41 % in the case of using the milling head with hydraulic clamping with back fixation of planing blades. The following equation describes the increase in the maximum height of the profile unevenness expressed by the surface roughness value R_z depending on the feed speed:

- Planing blades with back fixation R_z= 7.673.v$_f$ + 97.528 (R^2 = 0.996)
- Planing blades with back fixation R_z= 3.278.v$_f$ + 205.08 (R^2 = 0.891)

The reason for the increase in the surface roughness when increasing the feet speed lies in changing the trajectory of relative movement of the cutting wedge and, the spacing of protrusion on the surface and their height will increase.

Research in this area is realized almost exclusively under the direction of manufacturers of machines and tools, and mainly in the field of CNC machines. As the results show, the change of tolerance for cutting diameter circle of the tool has a positive impact on the product quality not only in the CNC machines, but also in the quadripartite milling machines.

CONCLUSION

The comparison of influence of method of fixing the planing blades into the milling head with hydraulic clamping and feed speed on the quality of created surface when milling by quadripartite milling machine reveals the higher quality when using the milling machine with hydraulic clamping and back fixation of planing blades compared to the milling Hydro head without back fixation of planing blades.

In the case of the milling head with hydraulic clamping and back fixation of planing blades, the surface roughness R_z, expressed as the maximum height of primary profile, is

45.552 μm, which is lower by 31% when compared with the milling head with hydraulic clamping without back fixation of planing blades (R_z =60.068 μm).

Further, it has been shown that the feed speed of material significantly influences the surface roughness of the machined material, independently of the milling head design with hydraulic clamping.

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