



THE QUALITY OF MILLED SURFACE IN RELATION TO THE STRUCTURE OF MILLING HEADS

Peter Janda – Mikuláš Siklienka

Abstract

The article deals with the issue of a plain milling by using three types of milling heads. 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 $v_f = 6, 15, 25 \text{ m}\cdot\text{min}^{-1}$. The comparison is made on a tangential spruce sawn timber with an absolute humidity of $w_a = 9 \div 12\%$, and with a cutting speed of $v_c = 58 \text{ m}\cdot\text{s}^{-1}$.

The article observes that the quality of the surface will improve by 31 % from the value of $R_z = 60,068 \mu\text{m}$ with milling Hydro head without back fixation of planing blades to the value of $R_z = 45,552 \mu\text{m}$ 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 with hydraulic clamping, feed speed, milled off clearance, tolerance of the cutting diameter of circle.*

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 (LISIČAN *et al.* 1996, KOCH 1985).

A four side 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, SVREŇ 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 (LISIČAN *et al.* 1996, LISIČAN and MÝTNY 1987).

The fixing of milling heads into the four side 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 (SADAK and NEGRI 2005), as well as (BARCÍK and KMINIAK 2008, 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 (GOGLIA 1994, OČKAJOVÁ A BELJAKOVÁ A SIKLIENKA 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: 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 four side milling machine **SK 908S** made by the company **SK Machinery - Taiwan** (Figure 1). The specifications of the milling machine are mentioned in Table 1.

Table1 Specifications of four side 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

Figure 1 Quadripartite milling machine **SK 908S**

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 with replaceable planing blades (from HSS 18 %W, dimensions: 35 x 3 x 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 $D = 180$ with replaceable planing blades (from HSS 18 %W, dimensions: 35 x 3 x 130 mm). The clamping pressure of milling head on the shaft is 30 MPa. The pressure agent is the lubricating grease NH2.

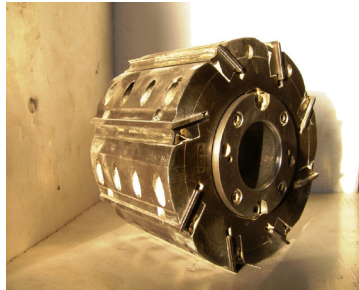


Figure 2 The milling head with hydraulic clamping without back fixation of planing blades



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

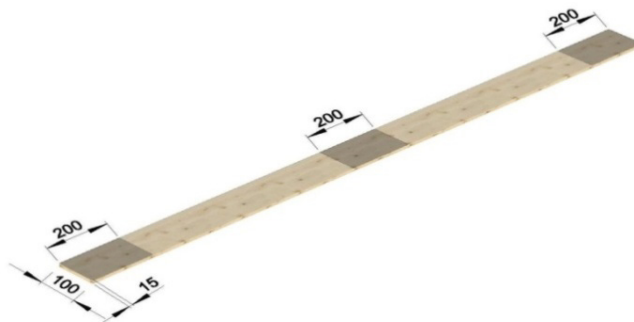


Figure 4 Selection of samples for the measurement of surface roughness

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.

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. illustrates the operating principle of Laser profilometer.

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 four side 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 **Tab. 2**.

Table 2 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 unevenness expressed as a roughness value R_z [μm]		
		Feed speed v_f [$\text{m}\cdot\text{min}^{-1}$]		
		6	15	25
hydraulic clamping	1200	58.64 (50.6426 - 60.6447)	59.96 (59.232 - 60.6943)	66.54 (62.9732 - 70,11)
	2400	32.77 (30.7351 - 38.7966)	45.62 (40.8351 - 50.4086)	74.58 (68.2337 - 80,92)
	4800	38.22 (36.3213 - 40.3057)	51.335 (47.4447 - 55.23)	77.52 (73.0355 - 82.0002)
	7200	45.62 (40.7318 - 50.5015)	52.72 (50.6752 - 54.7518)	83.46 (77.0523 - 89.8614)
	9600	52.51 (49.4201 - 55.5775)	57.88 (55.9622 - 59.7898)	85.09 (80.2144 - 89.9816)
classic clamping	1200	75.04 (70.0074 - 80.071)	63.15 (60.829 - 65.466)	75.51 (70.5186 - 80.4964)
	2400	43.16 (40.6728 - 45.6461)	66.25 (63.2758 - 69.2172)	80.31 (75.1869 - 85.4204)
	4800	54.64 (50.0549 - 59.2335)	71.52 (70.1578 - 72.8652)	87.37 (84.3333 - 90.4114)
	7200	59.69 (59.0765 - 60.2955)	78.36 (75.874 - 80.846)	95.69 (90.4906 - 100.8862)
	9600	67.81 (65.4647 - 70.162)	80.59 (79.5039 - 83.6717)	110.2 (100.00 - 120.392)

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 3**. 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.

Table 3 Basic table 3 – Multivariate Analysis of Variance (MANOVA)

Source of variability	Sum of squares	Degree of freedom	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 5 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 four side milling machine.

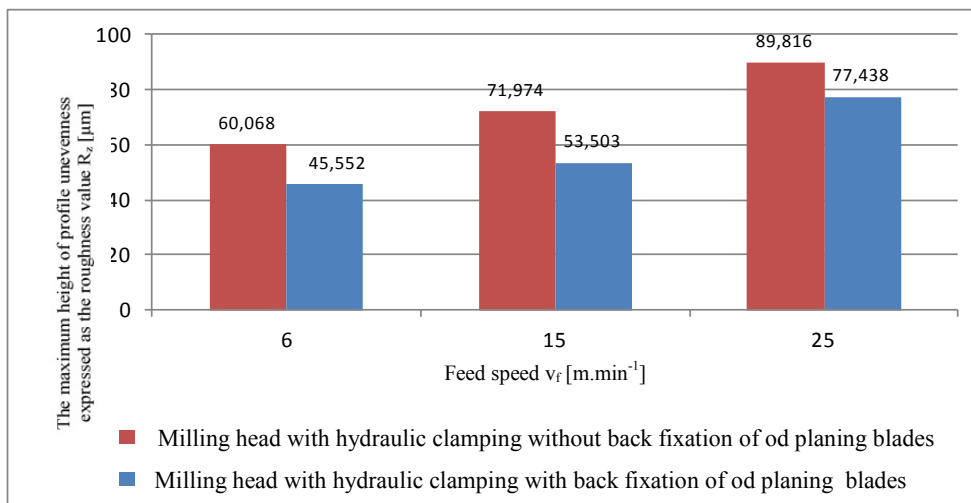


Figure 5 The dependence of surface roughness R_z [μm] on the feed speed of wood material when milling v_f [m.min⁻¹]

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 $R_z = 45,552 \mu\text{m}$. The average value of surface roughness, when using the milling head with hydraulic clamping without back fixation of planing blades, is $R_z = 60,068 \mu\text{m}$, 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. 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. 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 reason for the increase in the surface roughness when increasing the feed 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 four side 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 four side 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 ($R_z=60,068 \mu\text{m}$).

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. The following authors came to the same conclusion in their works: (Pivolusková, 2008), (Gáborik and Žitný, 2010). They also confirmed that the feed speed influences the quality of surface of the machined material.

ACKNOWLEDGMENTS

This work was supported by grants from VEGA no. 1/0725/16 „Prediction of the quality of the generated surface during milling solid wood by razor endmills using CNC milling machines.“

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