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Problems of the quality of wood machining by milling stressing the effect of parameters of machining on the kind of wood

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Abstract: *Problems of the quality of wood machining by milling stressing the effect of parameters of machining on the kind of wood.* The paper deals with the method of measuring the roughness of surfaces originating after milling. Effects of parameters of machining on kinds of wood were also studied. Results are demonstrated of measuring the roughness of surface of wooden samples of eight broadleaved species (ring-porous and diffuse-porous wood) and a conifer using a topographic method Talysurf. Evaluation of the experiment at selected species was carried out by means of parameters obtained using 2D and 3D photography. The actual evaluation of the surface quality was implemented by the Talysurf CLI 1000 apparatus. At the conclusion, an evaluation was carried out using the 2D and 3D surface measurement.

Keywords: roughness, modelling, milling, wood, topographic method

INTRODUCTION

Milling is a technological process serving for the creation of the surface of certain shape, dimensions and quality cutting material particles (chips) or wood fibre bundles (cutting operation). Fig. 1 demonstrates the kinematics of cutting a chip at standard milling (conventional milling). In practice, however, the actual chip cross-section can differ from the nominal cross-section due to blunting, inaccurate spindle run, deviations of cutting edges from the cutting circle, irregularities of the feeding device cycle and, particularly, due to splitting off and heterogeneity of the workpiece material.

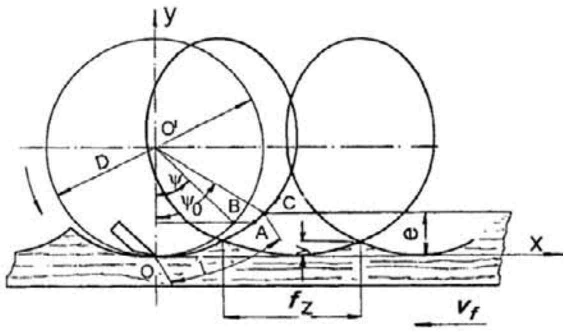


Fig. 1. Standard milling

The workpiece edge trajectory creates a cycloid curve, cutting speed being, however, very high at higher diameters of milling tools in proportion to the feed rate. Thus, at the section of the edge cut, it is possible to suppose with sufficient probability that its cutting track creates a circle.

Problems of milling and the machining surface quality were already several times examined being well processed at present. The paper is based on findings of authors and their publications (LISIČAN, 1996), (PROKEŠ, 1965), (SVOBODA E. et al., 2009) and a number of other foreign and Czech authors.

The process of the chip creation shows a fundamental effect on the workpiece surface quality and amply good him describing citation relations.

Feed per tooth:

$$f_z = \frac{v_f \cdot 1000}{n \cdot z} \qquad (1)$$

z … number of edges of a milling head (milling cutter)
v_f… feed speed of a workpiece [m.min^{-1}]

Considering the milling cutter edge creates a circle it is possible to determine the theoretical depth of the surface roughness (y) of milled surfaces up to hundredths of mm. Then, we can accept a known relationship to determine the wave theoretical depth y:

$$y = \frac{f_z^2}{4 \cdot D} \Rightarrow f_z = \sqrt{4 \cdot D \cdot y} \quad \text{[mm]} \qquad (2)$$

y.....depth of the surface kinematical roughness [mm],
D….the cutting edge diameter of a milling head [mm],
f_z …feed per the milling head edge

The relation (2) applies to absolutely accurate setting the milling head knives. In practice, it is rather often difficult to set up milling heads into a cutting edge with absolute accuracy. Thus, a situation demonstrated in Fig. 2 can occur.

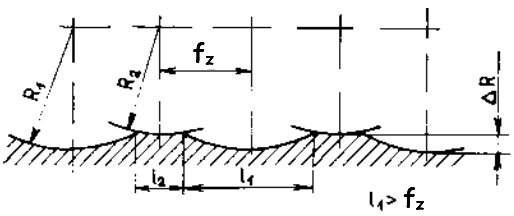


Fig. 2. The workpiece surface at the inaccurate setting the knives

Characteristic factors determining the surface quality of a milled workpiece are as follows: tree species, volume weight, mechanical properties, moisture content, and orientation of wood fibres with respect to the direction of the cutting edge movement. For the purpose of the paper it is sufficient when these factors are expressed by the tree species and its moisture content. The optimum moisture of wood is 8 ± 2%.

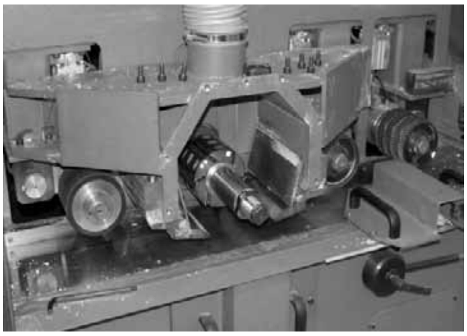
Kinetic roughness originates due to mutual motions of a milling head and a workpiece. Owing to the rotational motion of a milling cutter and usually the straight-line shift of a workpiece typical surface roughness originates, namely cycloid waves. The waves are characterized by their depth and the distance of their tops. This type of regular roughness is termed as waviness. Roughness arising from the wood structure results from the non-homogenous structure of wood and the different behaviour of early and late wood in the course of machining. It is assessed as irregular waviness. Picking-up the wood fibres is also related to the wood structure and behaviour. Torn bundles of wood fibres and microscopic and macroscopic cavities on the wood surface are characterized by their roughness (smoothness). The occurrence of this roughness is mostly irregular on the tooled surface.

MATERIAL AND METHODS

Used material and the experimental stand

- Evaluated species
  - ring-porous broadleaves – oak, elm, ash
  - diffuse-porous broadleaves – beech, birch, linden
  - conifers – spruce, pine
- Sample preparation
  - on an experimental milling stand
  - machine parameters – shaft speed 9000 rpm
  - feed speed 21 $m.min^{-1}$, chip thickness 2 mm
  - milling head – diameter 125 mm, height 100 mm
  - number of knives – 6, shaft bore – 40 mm
- Evaluation process
  - the Taylor Hobson company apparatus Talysurf CLI 1000
  - confocal sensor
  - 2 areas selected at each of the samples (17x17 mm), 3 sections at each of the areas

Note: The preparation of samples was carried out on the experimental stand



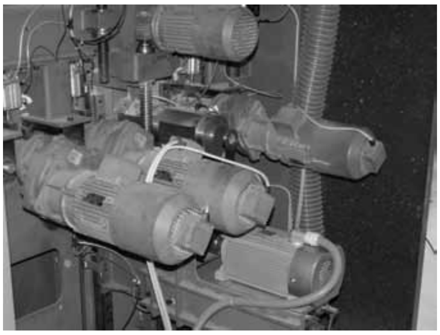


Fig. 3. Experimental stand – a view of the workplace and motor place

A method of the surface quality evaluation:

An optical method was used based on the topography of surface by means of a contactless confocal sensor CLA (Chromatic Length Aberration), which is part of a system for the surface texture evaluation (Talysurf CLI 1000). This system can carry out evaluation of the 2D (in total 117 parameters) and 3D (in total 40 parameters) surface structure.

The basic principle of the CLA confocal sensor is a fact that it does not create an image as a whole, at a time, but step by step through scanning. Thus, optical points are taken by means of scanning in the XY area and thanks to the accurate defined movement of the device objective in the Z axis also particular optical sections. Confocal images are always focussed representing particular optical sections through the sample. The composition of 3D images is based on a possibility of the gradual scanning tens up to hundreds of optical sections in the Z axis. Moreover, the confocal sensor uses the new intelligent software function of the calculation of foci (CFO), which selects always only the best displayed parts to create an image of the whole sample area. The speed of measurement, the more accurate quality of measurements and 3D images rank among its advantages.

Methods of the surface quality evaluation using the Talysurf CLI 1000 apparatus:

1. Levelling the surface = levelling the surface according to the selected area
2. Zoom = the selection of an area from the measured surface for further adjustments and analyses
3. Form removal = serves for the geometrical shape separation at measuring real surfaces
4. Thresholding = including the corresponding spectrum of data into analyses
5. Obtaining the basic area
6. Filtration – obtaining the area of waviness and roughness
7. Depiction of the 3D area
8. Determination of 3D parameters of the area surface structure

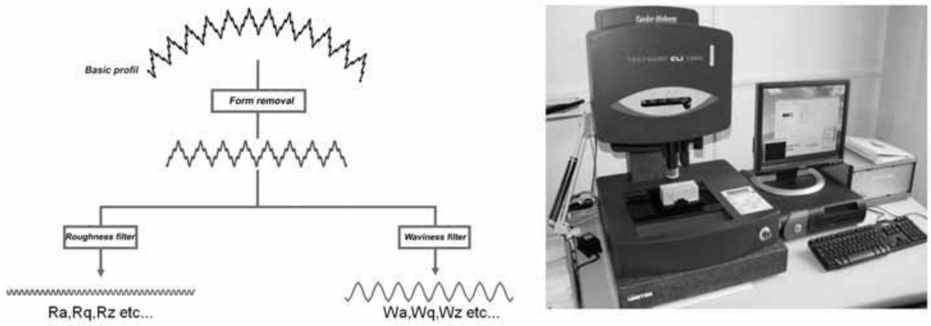


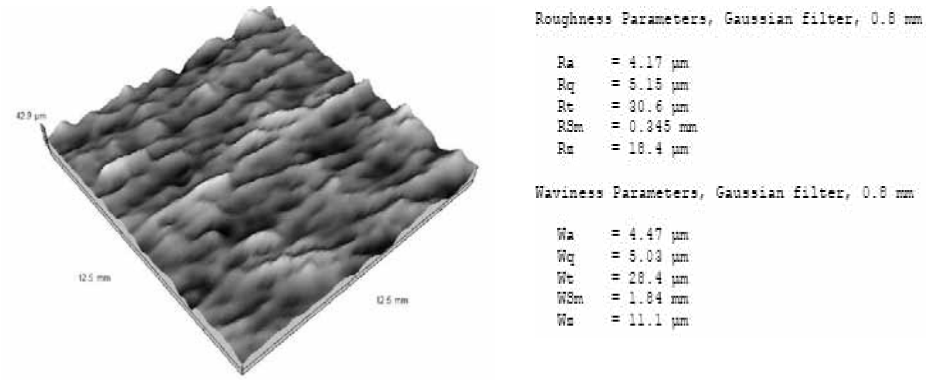
Fig. 4. Evaluation of the surface quality using the Talysurf CLI 1000 apparatus

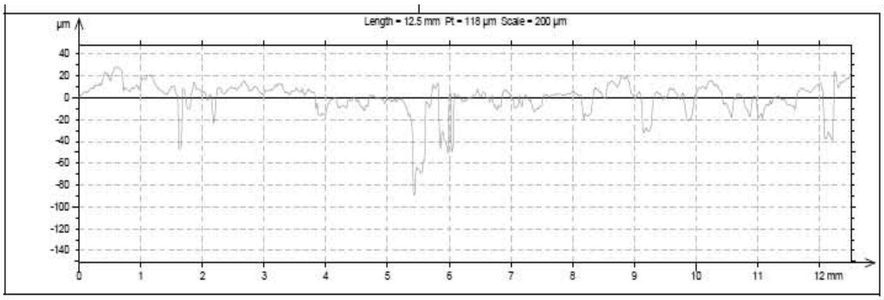
The surface of milled samples was evaluated using following parameters:

- S - parameter – the surface amplitude parameter
- R - parameter – a parameter calculated from the roughness profile
- W - parameter – a parameter calculated from the waviness profile
- Sa, Ra, Wa – the mean arithmetical deviation of a profile [μm]
- Sq, Rq, Wq – the mean quadratic deviation of a profile [μm]
- St, Rt, Wt – the total profile height [μm]
- RSm, WSm – the mean width of a profile [mm]
- Sz, Rz, Wz – the largest height of a profile [μm]
- Gaussian filter 0.8 and 2.5 mm was used at evaluated parameters

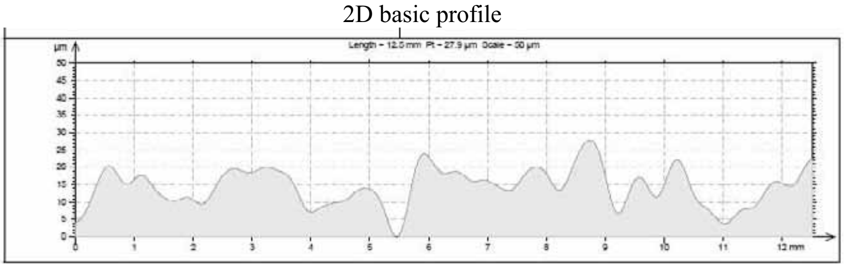
RESULTS

Results of the surface quality measurement were processed using the Talymap program in Talysurf system (see Fig. 8). An example is given of the 3D image of a beech sample, data on roughness and waviness and a selected section of the 2D basic profile, waviness profile and roughness profile.

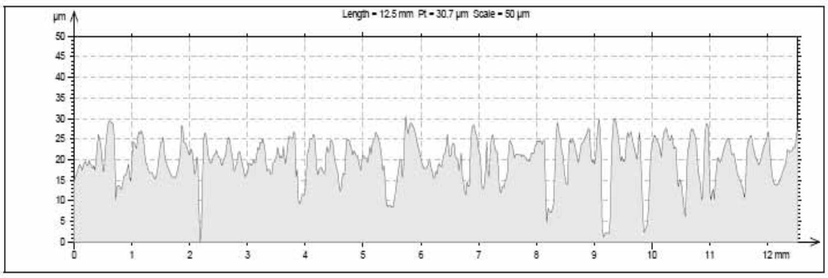




2D basic profile



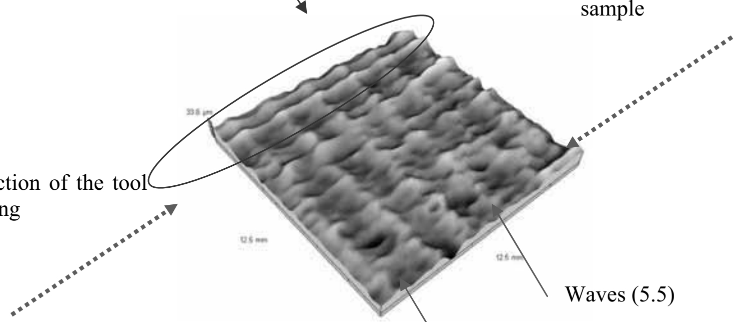
2D waviness profile

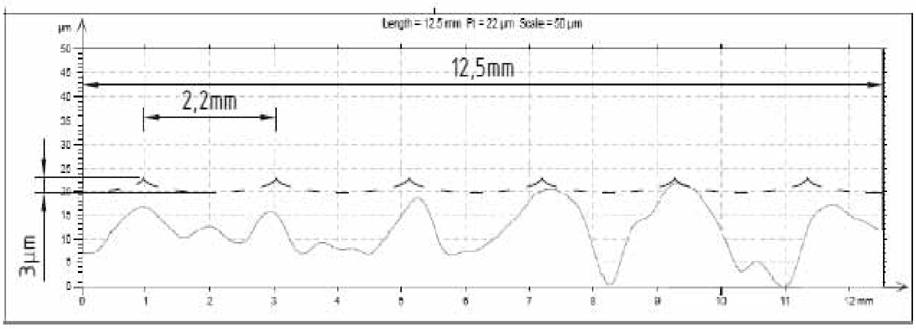


2D roughness profile

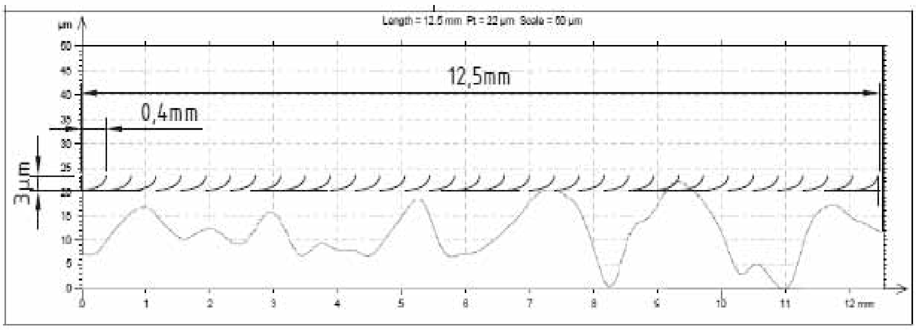
Fig. 5. Basic data on the surface quality of a beech sample from a PC

Through the processing of data it is possible to obtain waviness parameters, which can be compared with theoretically calculated values. Fig. 9 illustrates that the actual length of waves is higher than a theoretical value. Thus, an assumption is proved that all knives are not in gear.





The actual distance of waves – 2D profile of waviness



The theoretical distance of waves – 2D profile of waviness

Fig. 6. The profile of waviness of spruce at 9000 rpm, feed 20 m/min[-1]

Tab. 1. Values of roughness and waviness of experimental samples

	Oak	Beech	Ash	Elm	Birch	Pine	Linden	Spruce	
Sa [µm]	21,90	8,74	12,20	14,95	7,72	9,67	11,05	10,75	**parameters of the basic area**
Sq [µm]	33,65	11,60	21,10	23,85	10,29	12,00	14,10	14,50	
St [µm]	176,00	72,10	139,00	150,50	65,35	62,65	92,95	112,00	
Sa [µm]	13,30	5,47	8,17	8,74	4,68	7,43	8,83	5,38	**parameters of the waviness area**
Sq [µm]	18,10	6,96	11,25	11,95	5,86	9,13	10,90	6,89	
St [µm]	141,50	55,65	121,00	101,60	53,55	54,15	70,30	62,60	
Ra [µm]	1,30	1,16	1,72	1,60	1,21	1,77	1,62	2,53	**roughness parameters**
Rq [µm]	1,67	1,49	2,22	2,08	1,53	2,22	2,05	3,30	
Rp [µm]	3,07	2,76	4,18	3,67	2,87	4,29	4,03	16,58	
Rv [µm]	3,77	3,14	5,04	4,88	3,30	4,81	4,05	7,39	
Rt [µm]	13,80	11,95	18,10	17,60	12,00	15,89	15,20	27,98	
RSm [µm]	0,26	0,26	0,26	0,27	0,26	0,26	0,29	0,30	
Wa [µm]	3,45	2,87	2,53	3,23	2,71	2,78	4,35	3,97	**waviness parameters**
Wq [µm]	3,80	3,30	2,92	3,64	3,13	3,16	4,94	4,53	
Wp [µm]	2,58	2,62	2,84	2,76	2,71	2,90	3,68	4,08	
Wv [µm]	2,66	2,62	3,00	3,15	2,49	2,92	3,96	4,18	
Wt [µm]	18,78	17,30	16,00	20,25	15,33	15,52	25,32	26,97	
WSm [µm]	2,90	2,33	1,80	2,37	2,19	1,78	2,19	2,15	
Density(12%) [kg/m3]	725	720	710	680	650	535	505	450	
Hardness [MPa]	67,5	61	80	63	66	28,5	26	26	

ring-porous broadleaves
diffuse-porous broadleaves
conifers

DISCUSSION AND CONCLUSION

Measured parameters of the surface quality were then processed in the form of well-arranged tables (table 1). Only changes of the waviness parameters of W_z (Fig. 7) were processed in diagrams. Data on roughness were processed in the same way. However, these are of marginal importance to evaluate the surface quality of a work-piece.

To assess the effect of conditions of high-speed milling and a tool used it was necessary to evaluate particularly parameters of waviness and partly also parameters of roughness. By means of parameters of waviness it is possible to monitor kinematic unevenness, i.e. the process of high-speed milling, changes in the course of machining, machine and tool instability, changes in the operation of a cutting tool. By means of the roughness parameter it is possible to monitor effects of particular species on the surface quality or chipped (torn) grain.

The mean arithmetic deviation of parameters of waviness Wa ranges from 4.21 μm at 9000 rpm to 3.54 μm at 10000 rpm in spruce and from 4.73 μm at 9000 rpm to 3.92 μm at 10000 rpm in beech. The mean quadratic deviation of the waviness profile Wq ranges from 4.69 to 3.98 μm in spruce and from 5.3 to 4.41 μm in beech. With the decreasing feed per tooth these values diminish and, on the contrary, with increasing feed per tooth these values increase.

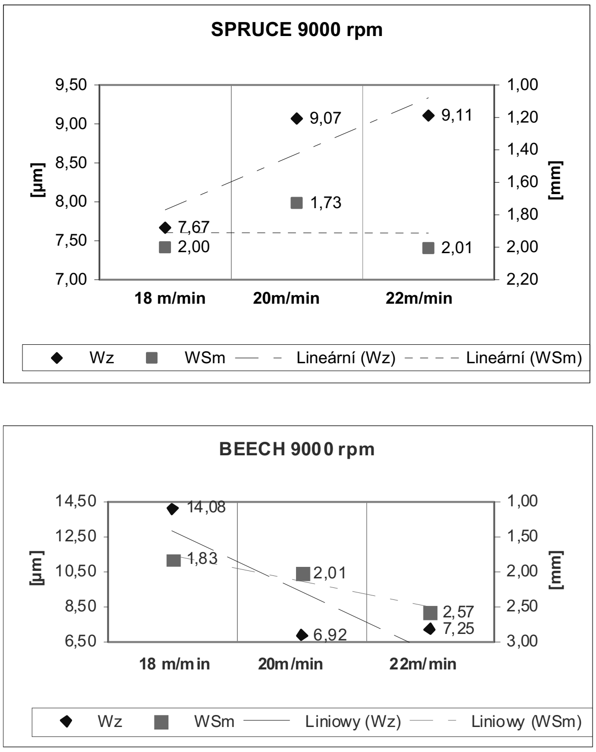


Fig. 7. Dependence of the waviness parameter on the change of cutting conditions

The surface quality measurement was carried out by means of 3D spatial characteristics making possible to process great number of data. The data then describe the assessed profile of the monitored surface. It will be suitable to measure more samples, which can demonstrate or disprove their dependence. Parameters of high-speed milling were selected with respect to maximum rpm of ordinary machines. The feed of material into cut was chosen according to a requirement to achieve the best possible quality surface. The average quadratic deviation of the waviness profile Wq corresponds to the theoretical calculation of the waviness depth being, however, about 2 μm higher, which can be attributed to the imperfect torn grain and thus, "hairy surface" originates. Differences in the Wq parameter among particular species are negligible and the growth of Wq with the feed speed was demonstrated.

Finally, it is possible to note that main advantages of the proposed method are as follows:

- it is possible to process a large number of data
- it is possible to predict surface properties

- it is possible to evaluate the surface preparation for spreading paint application
- the study of geometric and dimensional changes in various stages of the production process.

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Streszczenie: *Problematyka jakości obróbki frezowaniem uwzględniająca wpływ parametrów obróbki na rodzaj drewna.* Praca dotyczy pomiaru chropowatości powierzchni płaszczyzn po frezowaniu. Uwzględniono także wpływ parametrów na rodzaj drewna. Wyniki przedstawiają wyniki pomiaru chropowatości ośmiu gatunków liściastych (rozpierzchło oraz pierścieniowo naczyniowych) oraz jednego iglastego przy użyciu metody topograficznej Talysurf. Ocena jakości powierzchni wybranych gatunków została przeprowadzona na bazie parametrów otrzymanych przy użyciu 2D oraz 3D. Ocena jakości powierzchni została przeprowadzona na urządzeniu Talysurf CLI 1000. Przeprowadzono ocenę powierzchni przy użyciu pomiarów dwu i trójwymiarowych.

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