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EFFECTS OF THE TECHNOLOLOGY OF MACHINING ON THE SURFACE QUALITY OF SELECTED WOOD

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Abstract

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The paper deals with the dependence of using basic types of machining technologies on the surface quality of most common wood. In wood-processing industry, cutting by circular-saw blades and milling are the most often used technology to machining wood materials. The quality and accuracy of the machining are derived from the machine construction, shape and the amount of saw teeth, kind of wood species, feed per tooth and the size of the tool. Research was carried out on an experimental milling stand at setting various feed speeds and the spindle rpm, on an experimental cutting stand at using three types of circular-saw blades in the field of optimum and resonance rpm. Evaluation of the surface quality was carried out on a top multisensor apparatus Taylor Hobson-Talysurf CLI 1000 using a contactless method by a confocal sensor. Software equipment of a powerful computer was provided by the Talymap platinum program. Tree species were evaluated generally from the aspect of roughness and waviness altogether. An expert evaluation is carried out from two aspects. The first aspect is selection of the best technology for actual wood and the second aspect is selection of the best species for the actual technology. Particular relationships between wood and technology are evidently best described by graphs.

milling, cutting, surface quality, roughness, waviness

1 INTRODUCTION

In consequence of increasing the production capacities in timber and furniture industries demands on operational and technical properties of woodworking machines and tools steadily increase. Thus, rpm of tool spindles and the feed speed of materials fall into among the most important parameters of machines. Tool properties are determined by its geometry and material serving for its manufacture. These aspects markedly affect the tooled surface quality, which has to be checked to preserve the level of production quality. Until recently, the surface quality was evaluated only by subjective visual assessing and also by means contact method. In a large extent, all was affected by a person, who carried out this evaluation. By the gradual increasing the level of checking demands on increasing the quality control also increased.

The quality of machined surface in timber and furniture industries has to show corresponding properties, which are decisive for the further use of a particular product. The development of measuring technology and software equipment of the whole evaluation process contribute substantially to the surface texture evaluation. In new measuring processes, contactless methods of the surface sensing begin to be mostly used. These are more careful to the scanned surface being more accurate, more effective and faster compared to contact methods. Another contribution in the evaluation of the surface quality is the continuous development of software equipment. It is aimed not only at the control of the process of evaluation but above all at processing data obtained. It refers particularly to a fact that it is able to process huge amounts of evaluated data, which describe the actual spatial profile of the product surface. They can also provide functions of the real graphic depiction of the examined surface by means of an axonometric view, topographic map or the record of coordinate distribution. By means of the majority of surface characteristics we can not only increase the objectiveness of evaluation but, at the same time, to use them to predict the surface behaviour during use and operation, e.g. the sufficient readiness (preparedness) for subsequent surface treatments etc.

2 MATERIAL AND METHODS

2.1 Cutting

Cutting is a process when certain part is separated from the machined material by a tool in order to obtain necessary shape and dimensions of the product. Cutting is the most widespread method of partitioning basic construction materials entering the technological process of the furniture manufacture.

At cutting by a circular-saw, either a circular-saw blade shifts to a cut or a machined material, which is divided by the gradual cut of chips. Edges of the circular-saw blade move by a constant cutting speed along a circular track. At cutting, the rotational movement of a circular-saw blade comprises with a straight-line motion of a workpiece, i.e. the cutting track in the workpiece creates a cycloid curve. Cutting speed at comparison with feed speed is, however, as large that it is virtually possible to consider the cutting track to be a circular arc.

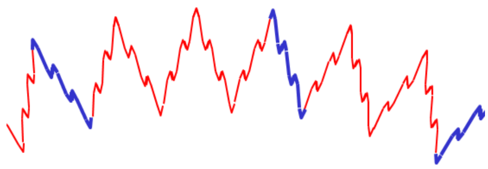
The rotational motion of a cutting tool and a uniform shift/feed causes a continuous change of the chip thickness. Kinematics of cutting by a circular-saw blade is demonstrated in Fig, 1.

2.2 Milling

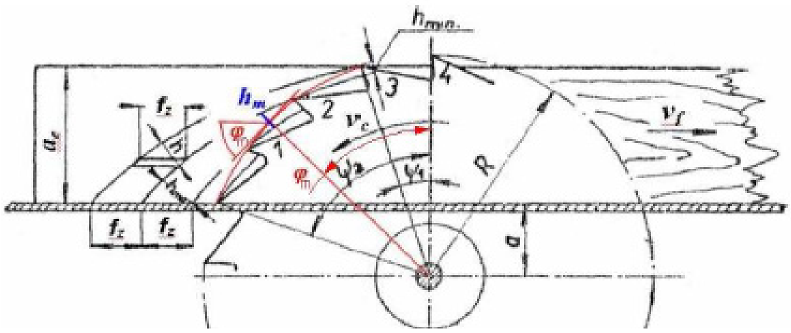
The technological operation of milling is defined as material machining by a milling cutter, which rotates and takes a chip of changing thickness from zero to maximum (h_{max}), feeding proceeds perpendicular to the axis of rotation. The kinematics of surface milling is demonstrated on Fig. 2.

2.3 Basic terms of the evaluation of quality

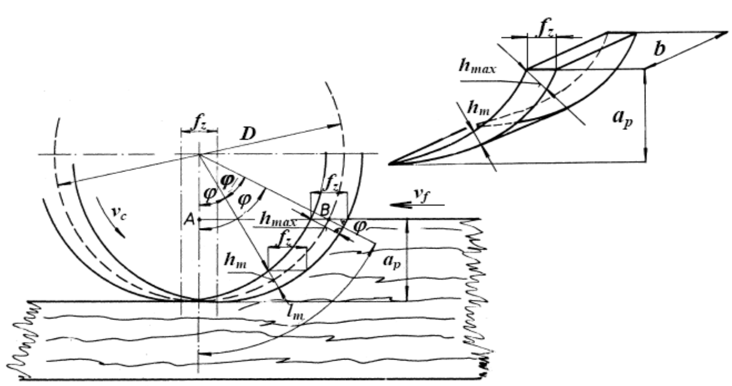
- **Roughness** – the smallest unevenness originating in the process of manufacture. Roughness is rather the consequence of the method of completion than the effect of a machine tool. A cutting tool leaves certain traces on the wood surface; the lay-out of traces is of periodic or accidental character. The parameter of roughness is marked by a letter R.



3: *Distinguishing the surface roughness*

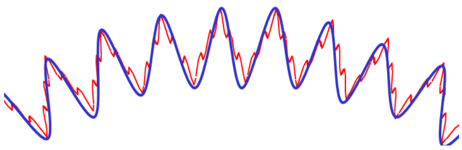


1: *The kinematic scheme of cutting by a circular-saw blade*



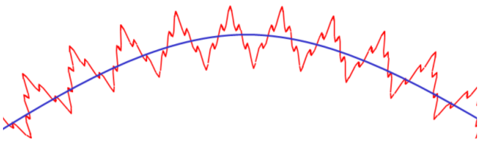
2: *The kinematic scheme of surface milling*

- **Waviness** – represents more dimensional unevenness, where roughness is superimposed; for the most part, it is caused by oscillation or the workpiece deformations. Waviness is attributed particularly to properties of the machine tool. The waviness parameter is marked by a letter W.



4: *Distinguishing the surface waviness*

- **Shape (form)** – is characterized by the largest unevenness of the surface profile, which originates regardless of roughness and waviness. Deviations of the surface shape are mostly caused by insufficiently stiff grip (chucking) of the machined part or deviations (indirectness) of guide surfaces of machines. The shape parameter is marked by a letter P.



5: *Distinguishing the surface shape*

- **Mean arithmetical deviation of Pa, Ra and Wa profiles –** a height parameter, which is obtained as an arithmetical mean of absolute values of ordinates Z (x) from the centre line within the range of a basic length.

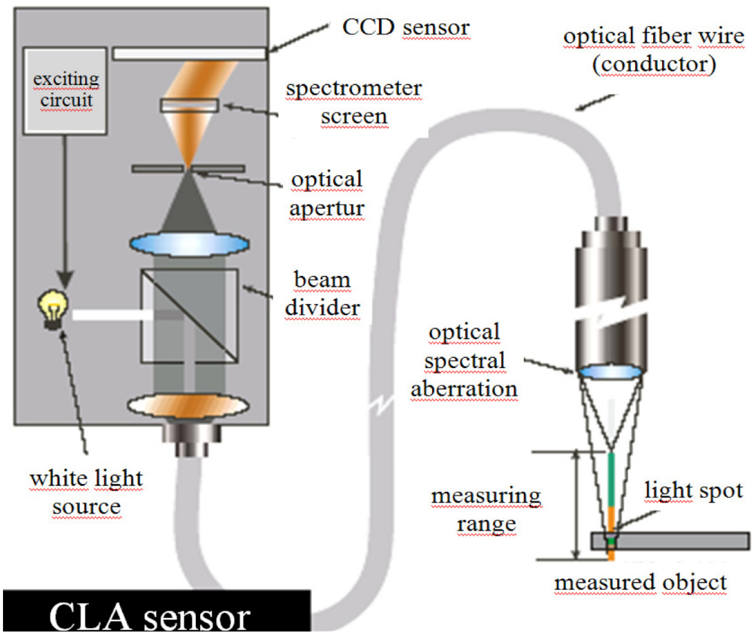
$$Ra = \frac{1}{lr} \times \int_0^{lr} |Z(x)|\, dx \,.$$

- **The largest height of the Pz, Rz and Wz** profile – the sum of height Zp of the highest profile projection (Rp) and the depth Zv of the lowest profile depression (Rv) within the range of a basic length.
- **Mean quadratic deviation of the Pq, Rq and Wq profile** – quadratic mean of ordinates Z(x).

$$Rq = \sqrt{\frac{1}{lr} \times \int_0^{lr} |Z^2(x)|\, dx} \,.$$

- **Total height of the Pt, Rt and Wt profile** – the sum of height Zp of the highest profile projection and depth Zv of the lowest profile depression within the range of an evaluated length.
- **Mean width of the PSm, RSm and WSm profile element –** basic characteristics of the surface roughness in longitudinal direction obtained as the arithmetical mean of widths Xs of the profile elements within the range of a basic length.

$$RSm = \frac{1}{m} \times \sum_{i=1}^{m} Xs_i \,.$$



6: *A scheme of the confocal sensor operation*

2.4 Confocal sensor (CLA)

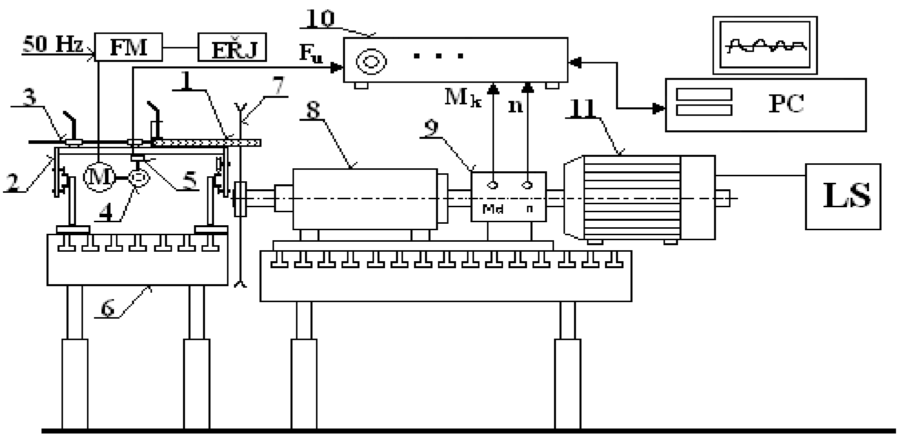
The principal of activity of a confocal sensor consists in the white light decomposition. Then, by means of optics with spectral aberration, it is aimed at checked surface. The optics decomposes light according to wave lengths and at each point of the surface only a certain wave length is focused. Light deflected from the surface comes through an opening (aperture), which transmits only light of the focussed wave length. A spectrometer will deflects light to a CCD sensor where a space position is allocated to every point (coordinates of the point X, Y and height in the given position Z). Advantages of this sensor consist in fast sensing at high resolution and high accuracy.

2.5 Experimental cutting stand

The experiment was realizeded on an experimental apparatus for cutting by circulare – saw blades.

In the experiment, a was used one circular-saw blade of a Slovak producer STELIT (designation K8) and two of circular-saw blades of a Czech producer PILANA (designation K9, K10). Parameters of which are given in Table I.

Procedure of the determination of cutting parameters is based on an analytical method. For all circular-saw blades, the same value was determined of the mean chip thickness h_m = 0.048 mm. At the same time, the course of vibrations was determined for each of the circular-saw blades and according to the course optimum and resonance rotational speeds were selected and the feed speed was calculated (Tab. II).



7: *The basic scheme of a cutting stand*
1 – machined piece, 2 – carriage, 3 – material clamping, 4 – ball screw, 5 – force sensor S2 –HBM, 6 – grid table, 7 – circular-saw blade, 8 – spindle, 9 – moment and rpm sensor T34 FN - HBM, 10 – Spider logger 8, 11 – electric motor, FM – frequency converter, EŘJ – electronic control unit, PC – computer, LS - Leonard apparatus

I: *Parameters of circular-saw blades*

	K8	K9	K10
Diameter of the circular-saw blade *D* [mm]	350	350	350
Number of teeth z	36	36	36
Diameter of a clamping hole *d* [mm]	30	30	30
Body disk thickness *a* [mm]	2.4	2.4	2.4
Tooth width s_T [mm]	4.45	4.45	4.45
Tooth height *h* [mm]	15	15	15
Tooth pitch t [mm]	irregular	30.528	30.528
Radial compensation grooves	yes	yes	no
Noise attenuation grooves	yes	yes	no
Radius of compensation rolling	no	0.66 R	0.66 R
Clearance angle α (°)	15	15	15
Sharpness angle β (°)	65	65	65
Cutting angle γ (°)	10	10	10
Skew angle of the flank ξ (°)	10	10	10

II: *Parameters of cutting:*

Circular -saw blade	Cutting velocity n [rpm]	Chip thickness h_m [mm]	Feed speed v_f [m.min^{-1}]
K8 (optimum/ resonance)	4 200	0.048	13.5
	3 800	0.048	12.2
K9 (optimum/ resonance)	4 200	0.048	13.5
	3 695	0.048	11.7
K10 (optimum/ resonance)	4 200	0.048	13.5
	3 700	0.048	11.8

2.6 Experimental milling stand

Another part of the experiment was working the surface of selected wood on an experimental milling stand under conditions of preset parameters using the method of standard milling (conventional milling). Parameters of milling were selected on the basis of experience of experts. Values of feed per tooth f_z were selected 0.3 and 0.6 mm. Cutting velocity of a milling head were set up first to 6 000 rpm and subsequently to 9 000 rpm (Tab. III). A milling head with a diameter of 125 mm and 6 cutting teeth of BENMET s.r.o. Prague was used.

III: *Parameters of milling*

Cutting velocity n [rpm]	Feed per tooth f_z [mm]	Feed speed v_f [m.min^{-1}]
6 000	0.3	10.8
	0.6	21.6
9 000	0.3	16.2
	0.6	32.4

2.7 Evaluation of surface

The last part of our experiment was to evaluate surface of all samples by a multisensor apparatus Taylor Hobson-Talysurf CLI 1000 using a confocal sensor and software equipment Talymap Platinum. Conditions of measurements and the procedure of evaluation are given in Tab. IV and V. The surface was evaluated according to EN ISO 4287 and ISO 12178-2 standards and parameters mentioned above were determined (R_a, R_q, RS_m, W_a, W_q, WS_m, …).

3 RESULTS

For this experiment, beech, oak, spruce and pine samples of wood were used. The system of results is created in such a way that at each of the sample blocks, an area 12.5 × 12.5 mm was selected according to a standard. After sensing the area, 3 cuts were selected and the evaluation of selected parameters was carried out on them. The value of Gaussian filter was preset to 0.8 mm.

On the ground of a large number of results statistical evaluation (average) was carried out gradually using the Excel program and these values were noted in well-arranged tables, which subsequently served for the preparation of diagrams and final evaluation.

4 DISCUSSION AND CONCLUSION

After assessing off all obtained results we can come to a conclusion that in practical operation it is not possible to evaluate roughness and waviness separately. They always occur on the wood surface in a certain combination and the human eye cannot differentiate waviness from roughness. Therefore, it is important to evaluate particular tree species generally from the aspect of roughness and waviness altogether. In this part, an expert evaluation is carried out from two aspects. The first aspect is selection of the best technology for actual wood and the second aspect is selection of the best wood for the actual technology. Particular relationships between wood and technology are evidently best described by table VI. Numerical evaluations originated on the basis of diagrams created from the tables and appearance properties of samples created by particular types of machining technologies.

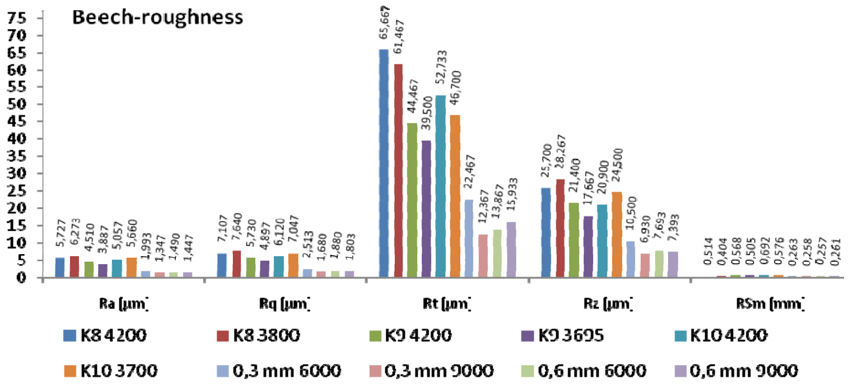
The expert evaluations are indicated in Table VI, which was established statistical quality evaluation

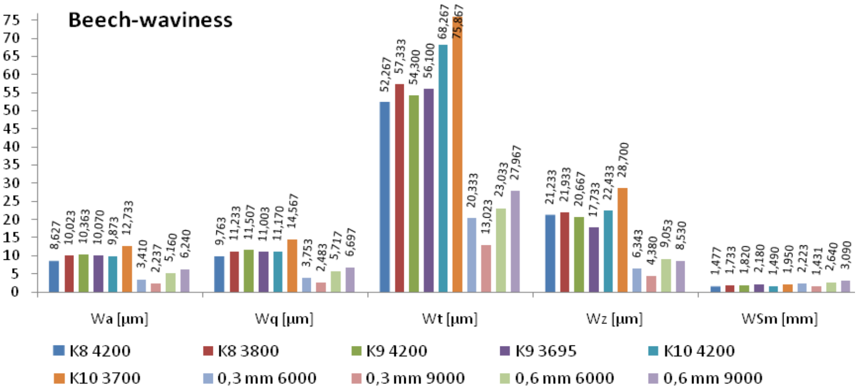
IV: *Conditions of measurements for Talysurf CLI 1000*

Sensor			Area	Step	Measurement speed
Type	Range/ sensitiveness	Frequency	X × Y		forwards/ backwards
Confocal	800 µm/30 nm	200–500 Hz	12.5 × 12.5 mm	20 × 20 µm	4 mm.s^{-1}/30 mm.s^{-1}

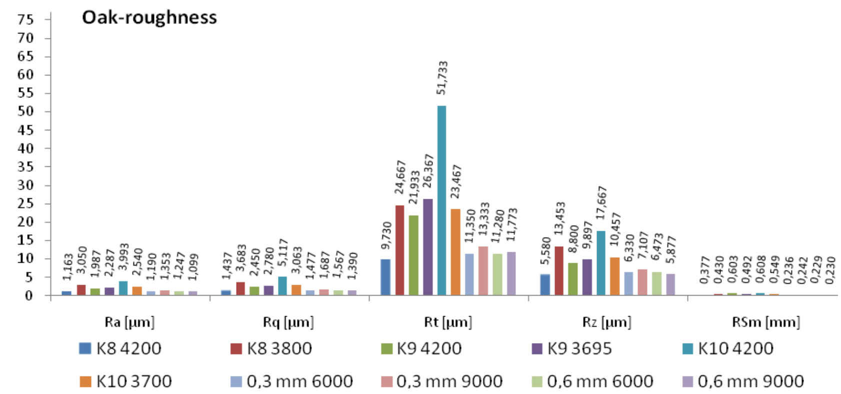
V: *Evaluation procedure*

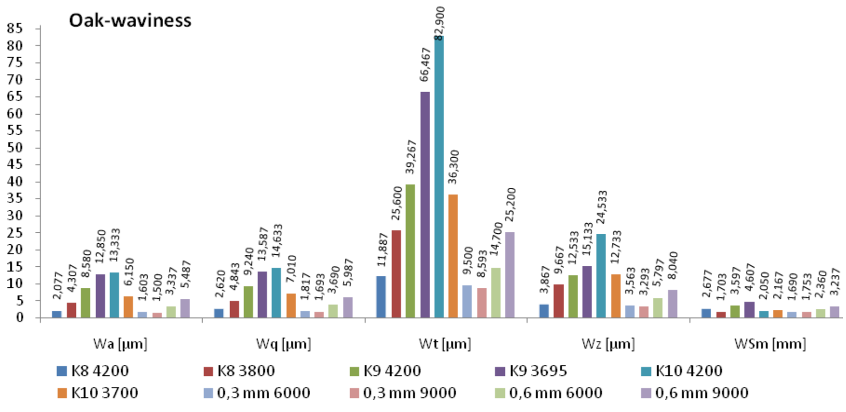
Operation	Description
Areas adjustment	Area adjustment according to a selected zone
Zoom	Area selection from the measured surface for further adjustments and analyses – elimination of edge deficiencies
Form removal	Detachment of a geometrical form at the measurement of real surfaces
Threshold	Involvement of the corresponding spectrum of data into analyses – obtaining a basic area



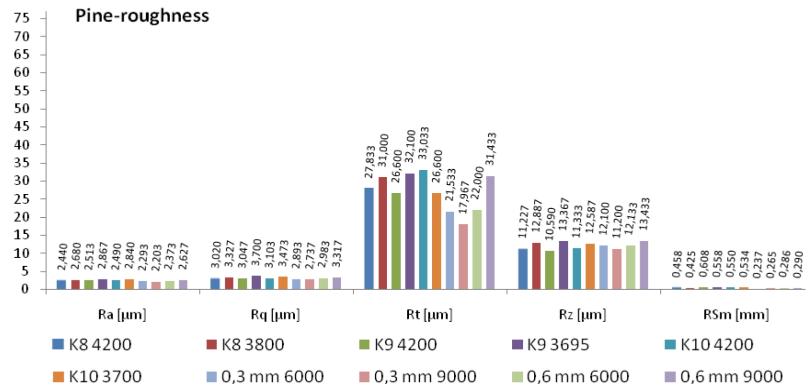


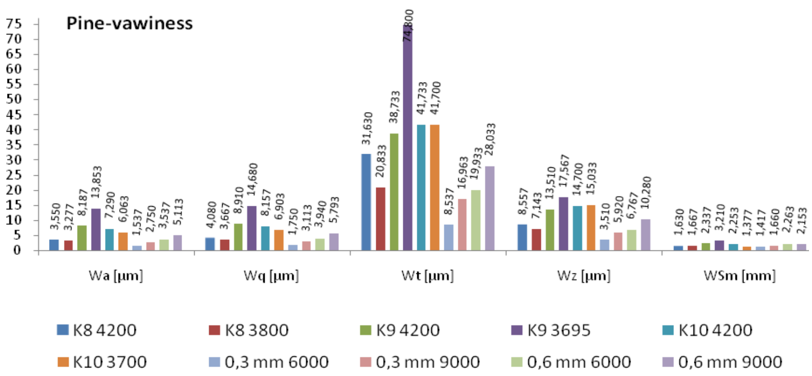
8, 9: *Average values of cutting and milling the beech*



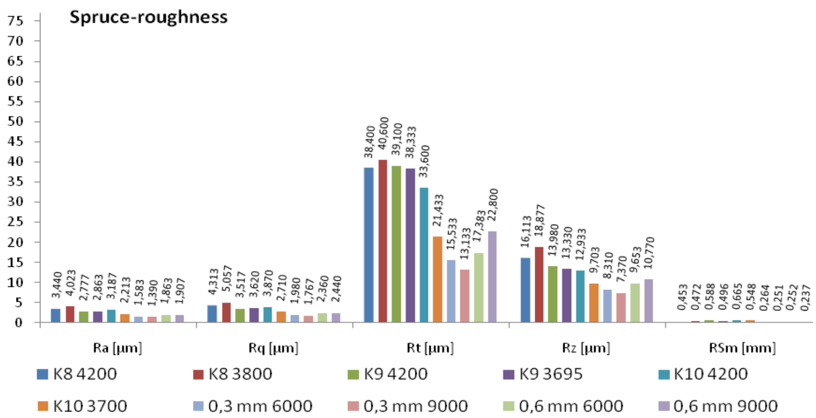


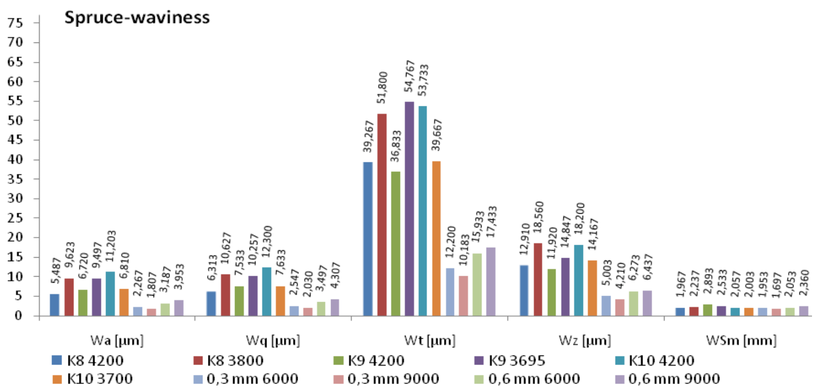
10, 11: *Average values of cutting and milling the oak*





12, 13: *Average values of cutting and milling pine*





14, 15: *Average values of cutting and milling spruce*

VI: *Effects of the technology of machining on the quality of wood surface*

	K8		K9		K10		MH, f_z =0.3 mm		MH, f_z = 0.6 mm	
	4 200	**3 800**	**4 200**	**3 695**	**4 200**	**3 700**	**6 000**	**9 000**	**6 000**	**9 000**
Beech	4	4	4	1–4	3–4	4	4	1–3	3	2
Oak	1	1–2	1	1–4	3–4	1–2	1	1–3	1	1
Pine	2	1–2	2	1–4	1	3	2–3	4	4	4
Spruce	3	3	3	1–4	2	1–2	2–3	1–3	2	3

(MH – milling head, 1 – best quality, 2 – good, 3 – bed, 4 – worst quality)

by four experts. The relationship of technology and machined surface is assessed relative to each other.

Of course, the actual anatomical structure of wood, its physical and mechanical properties and effects of the machine construction, the shaft stiffness, the tool blunting and many other factors participate to a great degree in all results. These effects cannot be eliminated; they always appear on the wood surface. Thus, it is important for practice, to determine or select such parameters of machining when the best surface quality will be acceptable.

According to results obtained it is possible to state that each of the tools acts differently at machining various kinds of wood and at setting various parameters. And also each of the tree species (wood) responds by another surface on the used technology of machining. Thus, it is necessary to select carefully cutting tools and to deal with the determination of technological conditions in the technological process.

Cutting and then milling are the first operations at machining the material. Therefore, it is very important to deal with these types of machining from the aspect of surface quality and the further use of the semi-finished product. Through setting correct/respective technological parameters it is possible to save considerable investments into other operations or maintaining the tools. Thus, it is important to monitor the resulting quality and to determine causes at deviations from steady parameters.

The surface quality is thus decisive for subsequent operations and the general aesthetics of products. The surface structure evaluation can contribute to understanding and dealing with a number of problems in the production technology. It makes possible the quantitative study of geometrical and dimensional changes of the surface profile in various stages of production processes after their finalization and in the course of their functional use.

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ČSN EN ISO 4288, 1999: Standard – Geometrical demands on products (GPS) – Surface structure: Profile method – Rules and procedures to assess the surface structure.

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