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Analysis of the influence of cutting parameters on surface roughness of milled wood based on Taguchi techniques

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Abstract: *Analysis of the influence of cutting parameters on surface roughness of milled wood based on Taguchi techniques.* Influence of cutting parameters (cutting speed, feed per tooth, height of cutting and tool wear) on the surface roughness of wood (obeche and spruce) after face milling was obtained in experiments. In conducted analysis of Taguchi method was used. Samples were machined on a CNC controlled milling machine. The Mitutoyo stylus unit (model SJ-201) was used in this study. Standard 2D surface parameter (Ra) used to evaluate of the smoothness. Only useful factor influence on surface quality during milling of obeche and spruce turned out degree of tool wear.

Keywords: wood, face milling, surface roughness, 2D surface parameter, Taguchi method

INTRODUCTION

Achievement of high quality in case of wood surface always seems to be great challenge. These difficulties are caused as by defects of wood, anatomic diversity of particular parts of wood structure as well variable in wide range properties (density, hardness, strength, modulus of elasticity). Influence of material properties on quality in area of wood machining is not very often appreciated in spite of its significant and often crucial importance. Many irregularities which occur on machined surface can be explained by result of its structure. Porous structure of wood never don't give ideal flat plane [Sandak and Negri 2005].

During modeling of real machined surface there is not sufficient to approve only kinematic parameters of machining but there must be taken into account additional factors which refer to machine and tool like e.g. tool wear, machine vibrations, way of work-piece holding or tool stiffness in handle [Sandak and Negri 2005]. Number of factors make level of correlation relationships between roughness parameters and particular factor low. [Magoss 2008]. This fact can be perceived as source of troubles during machining parameters optimization for given material. Taguchi technique is a methodology for finding the optimum set of the control factors to make the product or process insensitive to the noise factors [Ross 1996].

The aim of this work was analysis of tool wear influence, height of cutting, cutting speed and feed per tooth on surface roughness parameters in case of face milling of wood.

MATERIALS AND METHODS

Two wood species were used in researches (obeche and spruce) with low density (below 450 kg/m^3). This chose was not random because of fact that wood with low density shows tendency to fuzzy grain on machined surface. It means that this wood is much more inconvenient than wood with higher density. Basic physical and mechanical properties of investigated wood was showed in Tab.1. Workpieces with dimensions 300x120x25mm were used in investigations. Experiment was carried out according procedure described in work of Rousek et al. 2013. Machining was conducted on CNC BUSELLATO JET 130. Milling head LEITZ ID 041552, with diameter 180mm, equipped with five knives made from sintered

carbide mounted on ThermoGrip (Fig.1) was used. Face milling was realized in so way that half of wood surface was milled up and second milled down according to schema in Fig.2.

Tab. 1 Physical and mechanical properties of wood

Properties	OBECHE	SPRUCE
Density [kg/m^3]	385	428
Humidity [%]	6,1	7,4
Strength in static bending [MPa]	63,0	91,0
Modulus of elasticity [10^2 MPa]	53,4	82,0

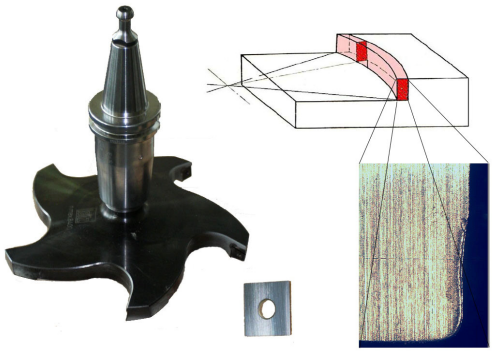

Fig. 1 Experimental planing cutter Leitz and wear of carbide blade

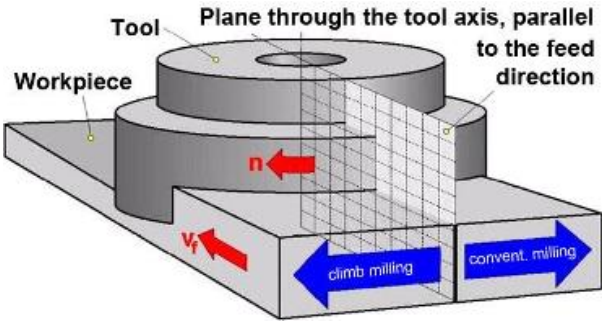

Fig. 2 Principle of face milling

The Taguchi optimization procedure begins with the selection of the orthogonal array with distinct number of levels defined for each factor (tool wear - VB_{max}, cutting height - h, cutting speed - V_c, feed per tooth - f_z). Each parameter was investigated at three levels (Tab.2). Array L_9 was selected, as shown in Tab.3. The Surftest SJ-201 MITUTOYO was used to measure the surface roughness (parameter R_a). Measurement was realized in two directions, along and across grains due to PN-84/D-01005. Exemplify surfaces of machined workpieces were showed in Fig.3.

Tab. 2 Assignment of the levels to the factors

	Levels		
Factor	**1**	**2**	**3**
Tool wear VB_{max}[mm]	0,0	0,1	0,2
Cutting height h[mm]	0,5	2,0	3,5
Cutting speed V_c[m/s]	50	75	100
Feed per tooth f_z[mm]	0,05	0,15	0,25

Tab. 3 Orthogonal array L_9 of Taguchi

L_9 Test	VB_{max}	h	V_c	f_z
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

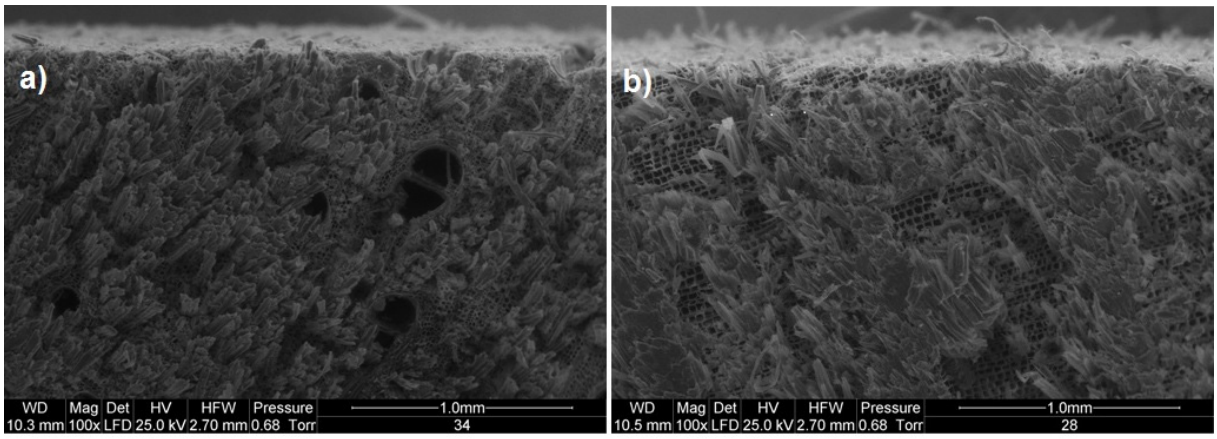

Fig. 3 SEM micrographs of machined surfaces (a- obeche, b-spruce): VB_{max} =0,0mm, h=2mm, V_c =75m/s, f_z=0,15mm

RESEARCH RESULTS

Analysis of measurement data was conducted in software STATISTICA 10 of firm StatSoft. Optimal cutting parameters are these which lead to minimize roughness parameter Ra, so that which allow to obtain the best quality of machined wood surface. Therefore there was decided to choose this kind of coefficient which means signal to noise (S/N) "smaller the better type". In below showed figures of extreme there are visible the best level of each input value (VB_{max}, h, V_c, f_z), which enable maximizing value of coefficient S/N. Marked lines in figures mean double range of standard deviation around mean Eta. It's worth to notice that only effect caused by changes of tool wear exceed limit of double range of standard deviation around mean Eta, as well during obeche (Fig.4) as spruce (Fig.5). Obviously optimal value of this factor is valid for new tool (VB_{max}= 0,0mm). So, usefulness of other factories (h, V_c, f_z) was doubtful. This phenomena is in relationship with influence of another factories not excluded in experiments but referred to anatomical structure of wood [Magoss 2008]. Modification of cutting height in investigated range, cutting speed or feed per tooth not allow to control efficiently roughness of investigated species of wood during face milling.

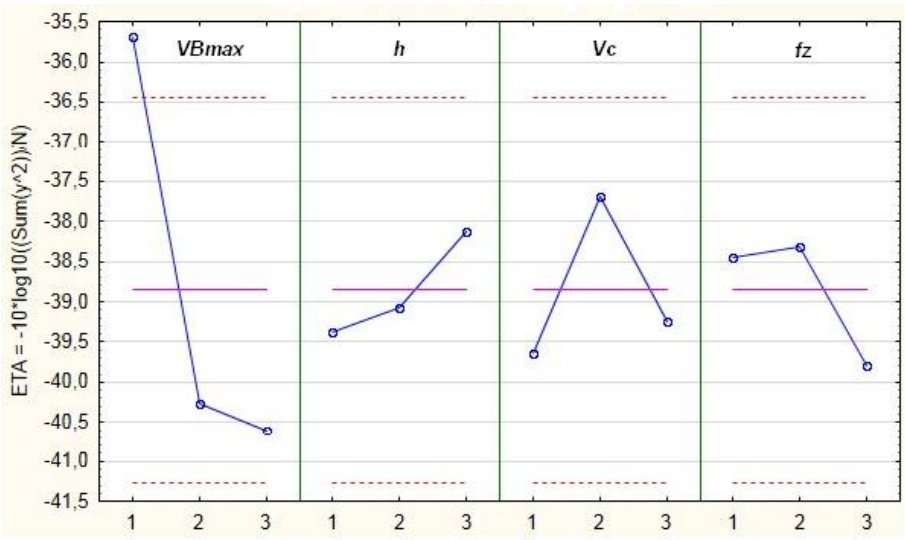

Fig. 4 Assessment of optimal cutting parameters during milling of obeche (climb milling, roughness measurement across grains)

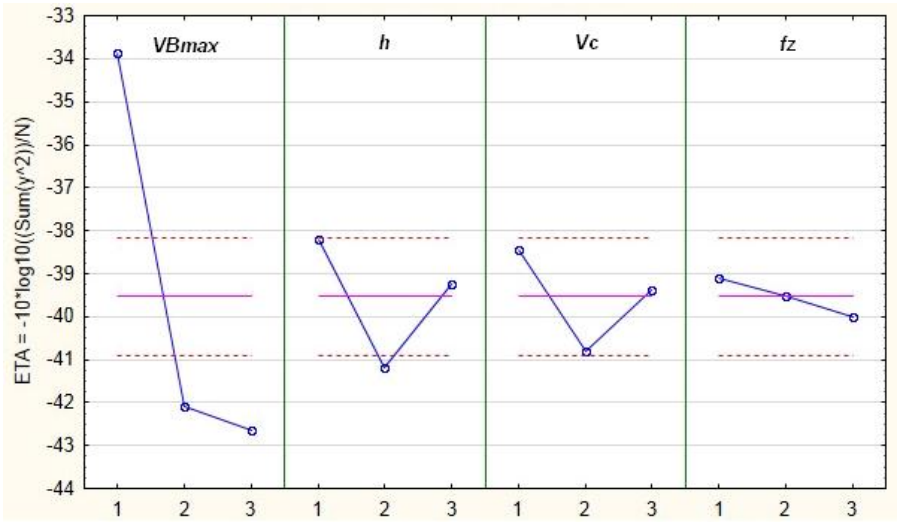

Fig. 5 Assessment of optimal cutting parameters during milling of spruce (climb milling, roughness measurement across grains)

CONCLUSIONS

The results are summarized as follows:

1. Only efficient factor which influenced on surface roughness during head-on milling of obeche and spruce turned out degree of tool wear. For spruce, impact of this factor was more distinct.
2. Other factors (height of cutting, cutting speed or feed per tooth) didn't prove useful influence on quality surface of both investigated species.

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Streszczenie: *Analiza wpływu parametrów skrawania na chropowatość frezowanej powierzchni z wykorzystaniem metody Taguchi.* W badaniach określono wpływ parametrów skrawania (prędkości skrawania, posuwu na ostrze, wysokości skrawanej warstwy oraz zużycia narzędzia) na chropowatość powierzchni drewna obecze i świerka po frezowaniu czołowym. W przeprowadzonych analizach posłużono się metodą Taguchi. Próbki drewna obrabiano na standardowym centrum obróbczym CNC. Pomiaru chropowatości dokonano z wykorzystaniem profilometru stykowego Mitutoyo (model SJ-201). Mierzono w dwóch kierunkach: wzdłuż i w poprzek włókien. Standardowy 2D parametr chropowatości powierzchni (Ra) wykorzystano do oceny jakości obróbki. Jedynie użytecznym czynnikiem wpływającym na chropowatość powierzchni podczas frezowania czołowego drewna obeche i świerka okazał się stopień zużycia narzędzia, przy czym dla drewna świerka wpływ tego czynnika był bardziej wyraźny.

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