THE EFFECT OF SELECTED FACTORS ON THE MILLED SURFACE QUALITY OF NATIVE SYCAMORE MAPLE WOOD AND THERMALLY MODIFIED SYCAMORE MAPLE WOOD

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ABSTRACT

The article deals with the issue of native sycamore maple wood and thermally modified sycamore maple wood milling on CNC machining centers. The milling of thermally modified wood is a very broad topic that deserves attention. The acquired knowledge concerning on the milling process may assist manufacturers improving the efficiency and quality of the process.

Article based on experiments in which was at 5 axis CNC machining center milled 30 mm thick sycamore maple board. In the milling process they were used finishing cutters LEUCO VFW 178354. The mean arithmetic deviation of the roughness profile was investigated during cylindrical milling of the board edges. This article focuses on finding the differences in the roughness of wood surfaces after surface milling of native sycamore maple wood and thermally modified sycamore maple wood and differing feed speeds (1-10 m.min-1).

In comparison with natural wood, thermal treatment had a negative effect on the quality of the wood surface after milling. The results also demonstrated an increased quality of surface finish with a decrease in feed speed.

Key words: thermally modified sycamore maple wood, surface roughness, feed speed, nominal thickness of the chips.

INTRODUCTION

Wood is a complex and natural material that consists basically of cellulose (40–45%), hemicelluloses (20–30%), and lignin (25–35%). Cellulose represents the crystalline area of the wood, whereas the structures of hemicelluloses and lignin make up the amorphous area. The main mechanical function of hemicelluloses and lignin is to buttress the cellulose fibrils (Wikberg and Maunu, 2004).

Wood materials can be degraded by attacks by numerous biological species and by environmental conditions, so they are protected by the use of various treatment processes. One of these processes is the thermal treatment of wood materials (Bourgois, Janin and Guyonnet, 1991).

The thermal treatment of wood is an environmentally-friendly method that is used for protecting wood. The thermal treatment process only uses steam and heat, and no chemicals or agents are applied to the material during the process. Testing of the wood after such treatment has shown that the treatment results in no harmful emissions when the wood is used in various applications (Požgaj *et al*. 1997).

When thermal treatment is applied, the cell wall components of wood (cellulose, hemicellulose, and lignin) are modified, and this modification changes the physical, mechanical, chemical, and biological properties of wood materials. Heat treatment has important effects on the color and chemical composition of the wood. Thermally treated wood has better durability, reduced hygroscopicity, improved dimensional stability, lower density than control samples, and darker color (Deniz, Gokhan and Seray, 2012).

The workpiece accuracy and the quality of a created surface can be regarded as an objective indicator of the quality of the created product. The workpiece accuracy presents the degree of approaching of the geometric values of the workpiece to the values set in the drawing, as the shape and dimensional accuracy is considered (Kminiak, Banski and Chakho, 2017).

An adequate accuracy is solved by CNC machining centers by the machine itself, therefore the quality of the worked out surface seems to be more important issue. The surface quality can be exactly defined by surface roughness parameters (Siklienka *et al*. 2017).

The surface shows some surface roughness during milling as well, such as microscopic changes (roughness) or macroscopic changes (waviness, grooves, elevations, partially drawn fibers). The occurrence of these changes (except waviness) on the workpiece surface is irregular (Korkut, Diziroglu and Aytin, 2013). The waviness consists of almost regular repetitive elevations and depressions of approximately the same shape and size (Gündüz, Korkut and Korkut, 2008, Novák, Rousek and Kopecký, 2011).

Roughness and waviness are, in fact, very small deviations from the desired shape, but they significantly affect the further processing of the workpiece, in particular its surface treatment (Aydin and Colakoglu, 2005, Očkajová *et al*. 2016).

Roughness and waviness depend on the kinematic conditions of cutting and are mainly influenced by the following factors:

- The way of separating chips, which depends not only on the method of machining, but also on the accuracy of a tool and its geometry.
- Cutting conditions (cutting speed, feeding rate, thickness of the removed layer, etc.).
- Microgeometry (dulling the cutting edge of the tool).
- Physical and mechanical characteristics of machined material (its density, hardness and structure) (Karagoz, Akyildiz and Isleyen, 2011).

The present article aims to evaluate the effect of wood heat treatment on the surface quality created within the spectrum of commonly used feed speeds.

EXPERIMENTAL METHODS

Experimental samples:

In the experiment were used native and thermally treatment sycamore maple blanks of dimensions width 30, thickness 55 and length 500 mm and the moisture content 8 ± 1%.

Thermal treatment of wood:

Sycamore maple wood in the form of blanks with dimensions 30 x 55 x 500 mm and humidity Wp = 58.2 ± 3.5% was thermally treated with steam in a pressure autoclave: APDZ 240 (LIGNOTHERM Ltd) at Sundermann s.r.o. Banská Štiavnica. The regime of thermal treatment of sycamore maple wood is given in Fig. 1 (Dzurenda, 2017).

Machine and tool:

Blanks were milled on 5 axes CNC machining center SCM Tech Z5 (Fig. 2) supplied by SCM–group, Rimini, Italy. Basic technical and technological parameters provided by the manufacturer are presented in Tabl. 1.

For milling was used finishing cutters LEUCO VFW 178354 (Fig. 3) supplied by LEUCO. Beinheim, France. Basic technical and technological parameters provided by the manufacturer are presented in Tabl. 2.

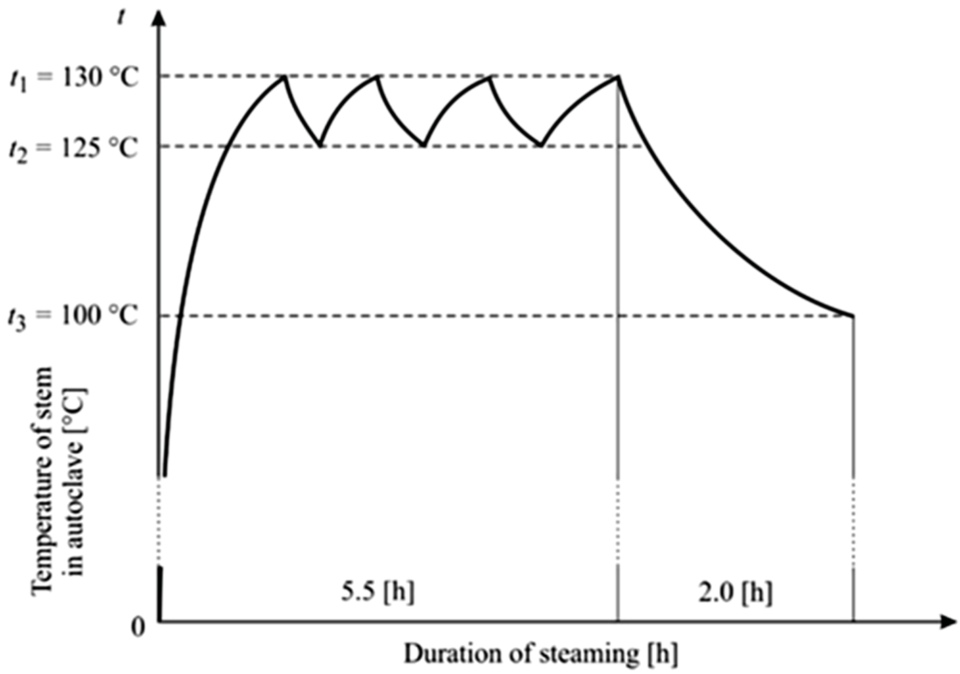

Figure 1: Regime of thermal treatment of sycamore maple wood using saturated water steam (Dzurenda, 2017)

Figure 2: CNC machining center SCM Tech Z5 (SCM Group, 2017).

Table 1: Technical and technological parameters of CNC machining center SCM Tech Z5 (SCM Group, 2017).

Technical parameters of CNC machining center SCM Tech Z5	
Useful desktop	x = 3,050mm , y = 1,300mm, z =300mm
Speed X axis	0 ÷ 70 $m.min^{-1}$
Speed Y axis	0 ÷ 40 $m.min^{-1}$
Speed Z axis	0 ÷ 15 $m.min^{-1}$
Vector rate	0 ÷ 83 $m.min^{-1}$
Technical parameters of the main spindle - electric spindle with HSK F63 connection	
Rotation axis C	640°
Rotation axis B	320°
Revolutions	600 ÷ 24,000 $ot.min^{-1}$
Power	11 kW
Maximum tool diameter	D = 160 mm L = 180 mm

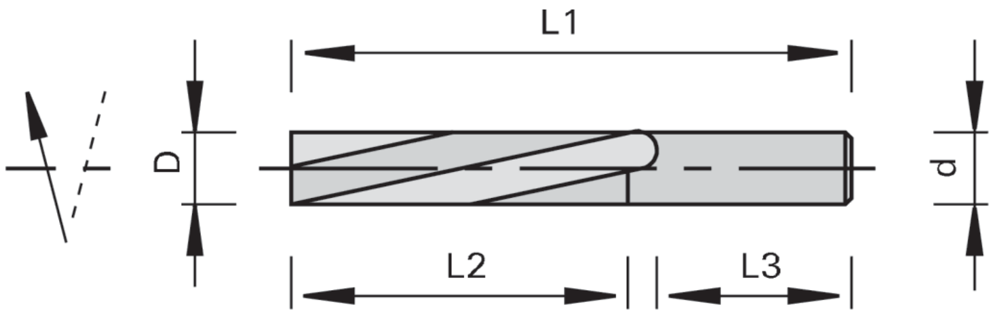

Figure 3: Finishing cutters LEUCO VFW 178354 (LEUCO, 2017).

Table 2: Technical and technological parameters of finishing cutters LEUCO VFW 178354 (LEUCO, 2017).

Feature	Value
Ø D = Cutting circle diameter	20 [mm]
L2 = Cutting width	55 [mm]
Ø d = Shank diameter	20 [mm]
L3 = Shank length	50 [mm]
L1 = Total length	115 [mm]
Z = No. of teeth	3
Helical direction = Helical direction	negative
n_{max} = maximum RPM	30,000 [min^{-1}]
L/R = cutting direction	R

Milling process:

A milling cutter was fitted into the hydraulic clamp SOBO. 302680291 GM 300 HSK 63F from Gühring KG Albstadt company. Sycamore maple blanks were placed in a CNC machining center so that the longer side was in the X-axis and the shorter side was in the Y-axis. Sycamore maple blanks were clamped during the milling by mechanical clampers VCMC-S4 145x145x50 12–80 from J. Schmalz GmbH, Glatten, Germany. The milling process was carried out at constant operation speed of cutter n = 20,000 min^{-1} and constant thickness of the removed layer f = 3 mm and changing feeding speed from v_f = 1 m.min^{-1}to v_f = 10 m.min^{-1}(representing a maximum feeding speed recommended by the manufacturer of the tools).

Determination of surface roughness:

The surface roughness of the samples was measured with a laser profilometer LPM-4 (Fig.4) by the manufacturer Kvant Ltd. Slovak Republic. The profilometer uses a triangulation principle of laser profilometry. The image of the laser line is scanned at an angle by digital camera. Afterwards, an object profile in cross-section is evaluated from scanned image. Obtained data are mathematically filtered and there are set individual indicators of the primary profile, profile of waviness and profile of roughness (Kminiak and Gaff, 2015).

There was used a methodology by Siklenka and Adamcova (2012) for measuring of the surface roughness that fulfills the standard EN ISO 4287. Within each sample, there were realized measurements in three tracks, located in the middle of the sample, evenly located across the width of the sample (5/10/15 mm from the sample edge), track length was 60 mm and the track was oriented in the direction of displacement of the spindle in a milling process. Surface roughness was evaluated by using parameter of arithmetic mean deviation of roughness profile Ra.

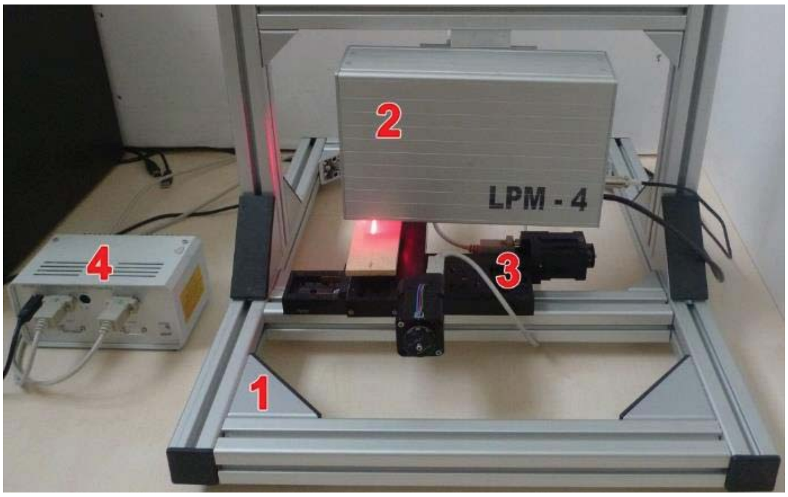

Figure 4: Laser Profilometer LPM - 4 (1 - supporting structure allowing manual setting of working distance and fitting of profilometric head and trolley system, 2 - profilometric head, 3 - feed system of the XZ axis, 4 - control system of working desk shifts) (Kminiak and Gaff 2015)

RESULTS AND DISCUSSION

The quality of the created surface was monitored based on the parameter the mean arithmetic deviation of the roughness profile Ra. The obtained data were prepared by a statistical analysis (Tabl. 3) which demonstrated that the influence of both monitored parameters (thermal modification and feed speed) are statistically significant. Average mean arithmetic deviation of roughness profile was in the interval 2.86 ÷ 4.12 µm in the case of native sycamore maple wood and in the range of 4.17 ÷ 6.34 µm for thermally modified sycamore maple wood. As shown graph in Fig.5 the influence of thermal treatment getting worse the mean arithmetic deviation of roughness profile of 1.25 µm. This at a mean value of the mean arithmetic deviation of the roughness profile of 3.51µm represents a 35% increase. However, the differences are not an eye or touch detectable.

Table 3: Multifactor analysis of the influence of thermal treatment and the feed speed on the mean arithmetic deviation of the roughness profile.

Univariate Tests of Significance for Arithmetic mean deviation of the surface roughness Ra [µm] /Sigma-restricted parameterization / Effective hypothesis decomposition

	SS	Degr. of Freedom	MS	F	p
Intercept	6139.014	1	6139.014	10188.69	0.00000
before/after thermal treatment	138.518	1	138.518	229.89	0.00000
feed speed	48.494	9	5.388	34547,00	0.00000
before/after thermal treatment*feed speed	53.664	9	5.963	33117,00	0.00000
Error	204.861	340	0.603		

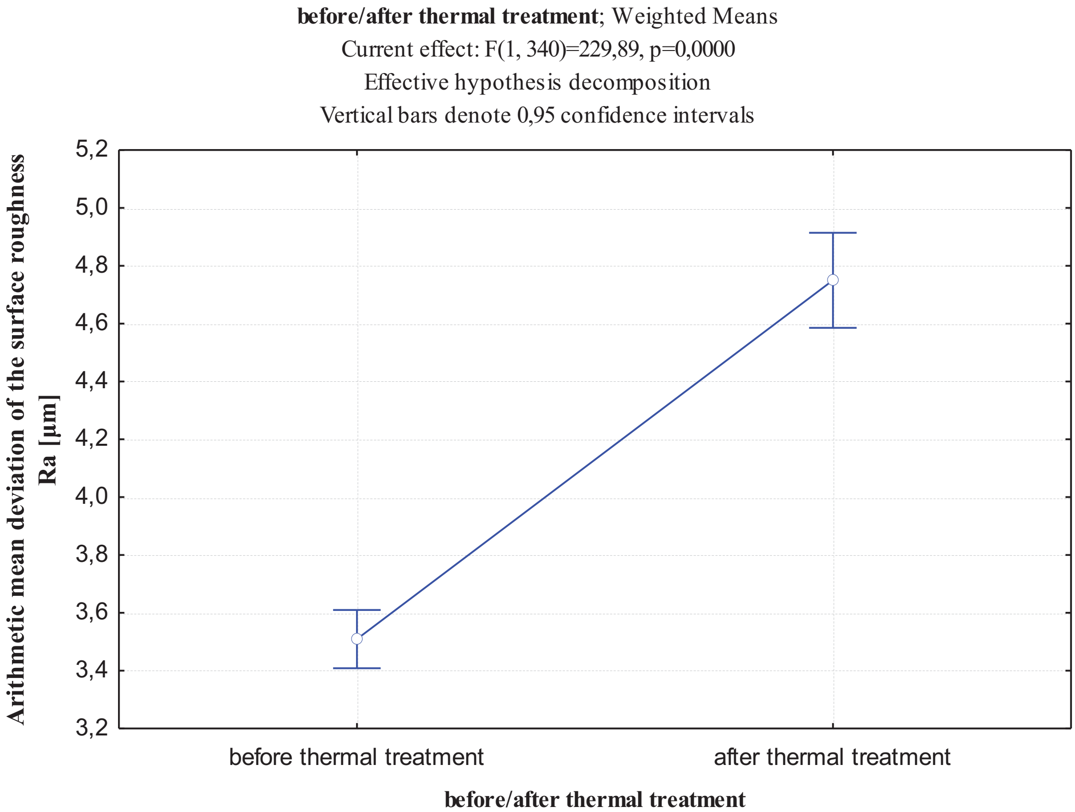

Figure 5: Dependence of the mean arithmetic deviation of the roughness profile on thermal modification.

In terms of the cause of differences in roughness values between natural and thermally modified sycamore maple, the kinetics and technical causes can be ruled out, they were excluded from the monitored factors and the methodology of the experiment, which focused on the technological causes. Because the thermal modification did not change the structure of the wood, this result was attributed to the changes in the physical and mechanical properties of the thermally modified wood. The change in physical and mechanical properties affected the formation of chips (the type of chip), the probability of formation, and the size and the size and direction of cracking during the formation of chips, which consequently change surface roughness (Kubš and Kminiak, 2017).

Thermally modified wood is generally considered more „fragile“ and subsequently more susceptible to cracking, which can either be an advantage or disadvantage depending on the direction of the cracks.

Dependence arithmetic mean deviation of roughness profile from the feed speed is in the graph in Fig. 6.

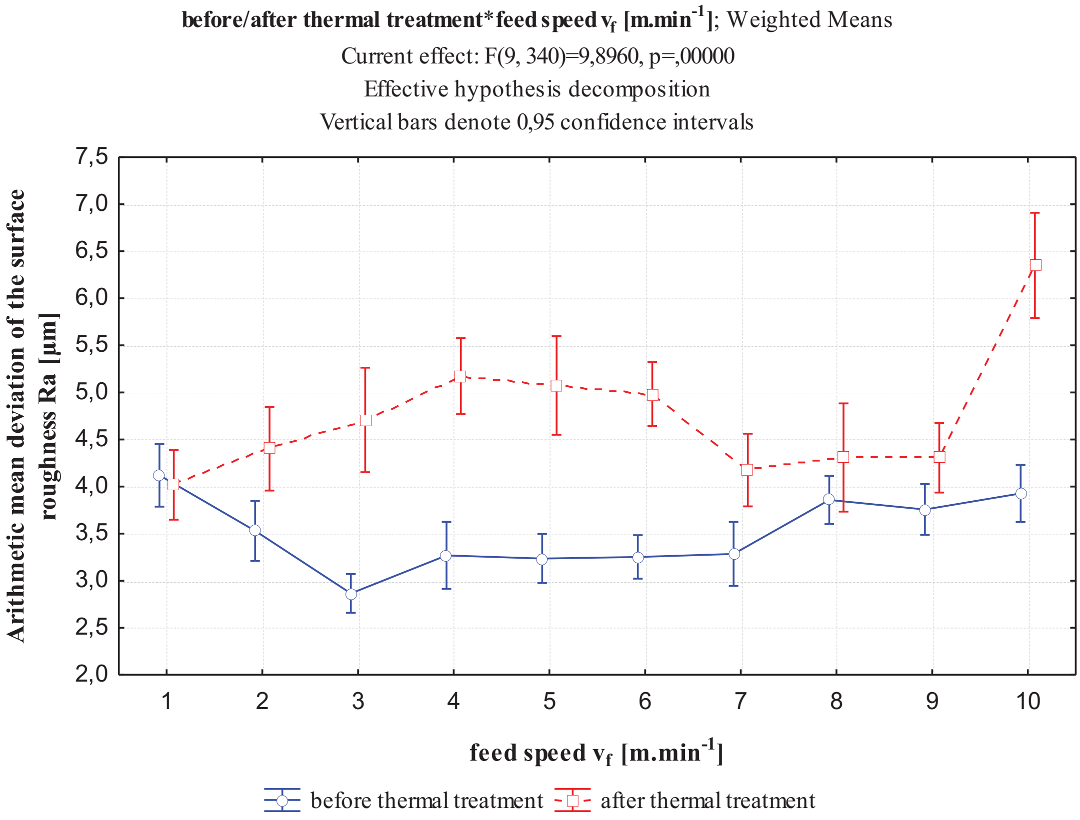

Figure 6: Dependence of the mean arithmetic deviation of the roughness profile on the feed speed.

The results confirm the assertion by Gaff, *et al*. (2015) the effect of the feed speed is observable within both parameters such surface waviness and the surface roughness. Within the presented results it is not possible to record a clear trend and thus not to confirm the claim Barcík, Pivolusková and Kminiak (2008) and Kvietková *et al*. (2015), at constant spindle speed and increasing feed per tooth is deteriorating quality of the generated surface. It should be emphasized that the feed speed determines the parameters of the cycloidal motion, influencing the parameters of the kinematic waves on the surface and thus hiring the surface waviness (Nemec, *et al*. 1985). However, as Barcík, *et al*. (2009) notes, decreasing the feed speed reduces the wavelength spacing as well as their depth while at the same time lowering the fibres, which affects the waviness of the formed surface. The difference between the lowest and highest values of the mean arithmetic deviation of the roughness profile was 1.26 µm for natural wood and 2.18 µm for thermally treated wood.

CONCLUSIONS

The average arithmetic mean deviation of roughness profile was 3.51 µm in nature wood and 4.75 µm in thermally treated wood. Thermal treatment of wood will affect surface roughness – cause its deterioration in diameter by 1.25 µm. Feed speed affects surface roughness but it is not possible to record a unambiguous trend in the obtained values. Within the interval of the measured speeds of 1–10 m.s^{-1}, the values of the mean arithmetic deviation of the profile will be roughly 1.26

μm for natural wood and 2.18 μm for thermally treated wood.

Differences due to thermal treatment and also to the effect of the feed speed, however, are not an eye or touch detectable

ACKNOWLEDGMENTS

This article was created with the support of VEGA 1/0725/16 "Prediction of the quality of the generated surface during milling solid wood by razor end mills using CNC milling machines." and support of VEGA 1/0485/18 "Machining strategy for special cutting models of agglomerated materials in nesting machining on a CNC machining center".

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UNIVERSITY OF FORESTRY

International Scientific Journal

INNOVATON IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

Volume VIII Issue 1 Year 2019

ISSN 1314-6149 e-ISSN 2367-6663

UNIVERSITY OF FORESTRY

FACULTY OF FOREST INDUSTRY

INNOVATION IN WOODWORKING INDUSTRY AND ENGINEERING DESIGN

1/2019

INNO vol. VIII Sofia

ISSN 1314-6149
e-ISSN 2367-6663

Indexed with and included in CABI

CONTENTS