Machining of Wood Plastic Composite (Pilot Experiment)

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The paper deals with a comparison of the surface roughness of WPC (Wood Plastic Composite) after the machining (turning). Turning was performed with constant speed rotation and constant depth of cut. The goal of this paper was the observed change of average maximum height Rz (roughness average Ra) with change of feeds (interval of feed f=0.1 to 0.61mm) and design recommendations resulting from acquired knowledge.

Keywords: Wood Plastic Composite, machining, surface roughness

Wood Plastic Composite (WPC) is gradually expanding to interior and exterior products market. This material represents favourable alternative to artificial plastics and natural materials. WPC excels in many specific properties, minimal maintenance and affordability. In that it becomes exceptional for a consumer. Therefore, it is needed to make an effort to better understanding of these properties and quality of machined surfaces of this material. Although the exact shape and profile (hollow and full) can be obtained by the process of extrusion, in some applications the conventional technologies (cutting, turning, milling, planning or grinding) are also needed to be used. The development of new material with specific features requires the continuous technologists focus on their possibilities of machining and quality of surface after machining [1]. Many studies report biodegradation (effect of fungi and bacteria) [2, 3] or photodegradation [4] durability [5], change of chemical properties [6], influence of the volume and sort of wood component on mechanical properties of WPCs [7] etc. A complex study is a publication entitled Wood-plastic composite (2007) and which describes history, properties, standards of tests (ASTM tests) and the options of the applications [8]. However, only a tiny percentage of studies deals with an observation of the surface microgeometry after the machining. One out of the available is also a publication: Wood Fiber – Plastic Composites: Machining and Surface Quality, written by U. Beuhlmann, D. Saloni and R. L. Lemaster. The research was managed by a programme Wood Machining and Tooling Research Program at North Carolina State University. The programme dealt with tool wear and quality of the surface after the machining of the WPC materials (used commonly in fencing and decking industry). Tungsten carbide knives (blade carbide grade Sandvik H3F – 3% cobalt binder with ultra-fine carbide grain 0.5 – 0.9 μm) were used in process of the machining (routing). Final statement is as follows: “Roughness of the surface after the machining is similar to the one of wood (in comparison to the control sample of white pine).” However, the tool wear is up to as much as six times higher compared to the control sample (white pine). Belt durability was also evaluated and as a comparative sample they used traditional hard maple [9]. The results are described in table 1.

Table 1
COMPARISON OF THE BELT LIFE [1]

Material	Belt life [min]
CHOICEDEK[1)]	40
FIBERON[2)]	150
SMARTDECK[3)]	40
TREX[4)]	31
MAPLE	54

[1), 2), 3), 4)] WPC materials produced by different manufacturers

Table 2
EXAMINED MATERIAL (INFORMATION FROM DEALER)

Describing of material	
Product designation	megawood
Material	polymer bonded wood material
Use	40
Chemical composition	70% wood, 30% HDPE
Colour	brown
pH value (with 100g/l H_2O and 20°C)	4,5 – 6,5
Melting point	Not applicable
Form	Pellet
Use	Production of extruded profile and injection moulding elements

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Experimental part

Materials, conditions and equipment

For purpose of an experiment WPC material, as described in table 2., was used.

Cutting tool: Experiment was carried out using a centre lathe (TOS Kurim). In the process of cutting, a tool from HSS: EN ISO HS6-5-2, was used. Geometry of the cutting tool: tool orthogonal rake $\gamma_0=20°$, tool orthogonal clearance $\alpha_0=8°$, tool cutting edge angle $\kappa_r=45°$, tool nose radius $r_\varepsilon=0{,}5$mm, tool included angle $\varepsilon_r=90°$. Cutting conditions during turning: speed of rotation n=900 m/min (constant), feed f=0.1 to 0.61mm (sample No. 1 – f=0.1mm, sample No. 2 – f=0.2mm, sample No. 3 – f=0.3mm, sample No. 4 – f=0.41mm, sample No. 5 – f=0.61mm), depth of cut ap=0.5mm (for turning of final diameter d=36mm). Cutting environment – without cutting fluid (material is on the basis of wood).

Preparation of samples

As the material is extruded (profile) it was very difficult to find a profile with circle cross-section. Dimensions of extruded profile were 60x40x3600mm. Steps of preparation:

- step 1: cutting by hack saw machine → pieces with 100mm in length
- step 2: milling → samples with square cross-section (prior to turning – fig. 2)
- step 3: turning to 37mm in diameter (fig. 3) and then to 36mm in final diameter.

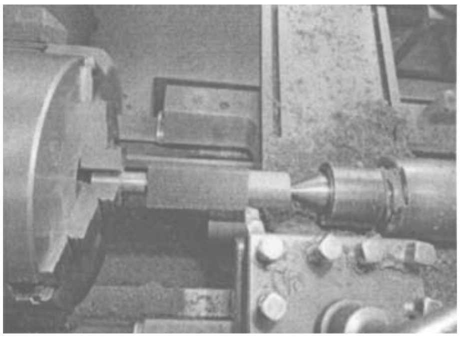

Fig. 1 Clamping work (the carrying spike and popped heat)

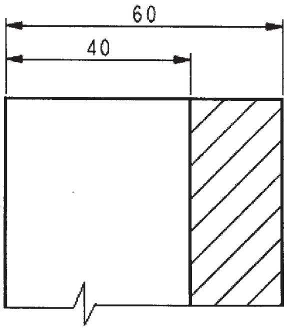

Fig. 2 Step 2: milled volume

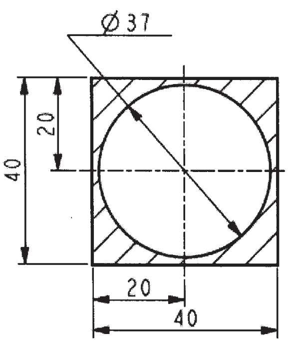

Fig. 3 Step 3: turning to 37mm in diameter

Measurement parameters

Surface roughness is usually related to tool path (for example turning or grinding) [10]. Quantitative evaluation of average maximum height Rz (is the arithmetic mean value of the single roughness depths of consecutive sampling lengths. Rz is the sum of the height of the highest peaks and the lowest valley depth within a sampling length) and roughness average Ra (is arithmetic average of the absolute values of roughness profile ordinates, Ra is the area between the roughness profile and its mean line, or the integral of absolute value of the roughness profile height over the evaluation length) – according to ISO 4287. MITUTOYO SJ-400 was used for measuring, measuring length=4,0mm, filter of profile $\lambda c=0.8$mm ($\lambda s=2.5\mu m$). Roughness was measured on the surface (after the machining) in place 1, 2, 3 (fig. 4).

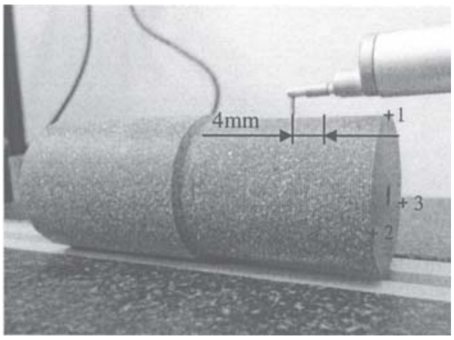

Fig. 4 Measuring of parameters in place 1, 2, 3 (angle-wise 120°)

Results and discussions

The values were tested by GRUBBS TEST and the values with a gross error were excluded (extreme values). Calculation of the average value Rz (or Ra) for the individual feeds (1):

$$\overline{Rz} = \frac{1}{n} \cdot \sum_{u=1}^{n} Rz_{un} \tag{1}$$

Standard deviation for individual feeds (2):

$$s_n = \sqrt{\frac{\sum_{u=1}^{n} \left(Rz_{un} - \overline{Rz}\right)^2}{n-1}} \tag{2}$$

Calculation of standard value (3):

$$H_{\min(\max)} = \left| \frac{\overline{Rz} - Rz_{\min(\max)}}{s_n} \right| \tag{3}$$

If H_{min} or H_{max} value exceed the critical value for GRUBBS TEST at a corresponding of freedom and significate of 0.05 at level of accurancy +/–5%, it was established as a gross error. In this case no gross error occured.

Interpretation of results

The place with the lowest values Ra (or Rz) was selected out of the places 1, 2, 3 on every sample. Following that dependability of roughness parameters on feeds (at constatnt speed of rotation n=900 m/min) was also created.

Places with major surface unevenness appeared on the samples, which were machined at the higher feeds (samples No. 3, 4, 5) after the turning.

It is clear, that values Rz (or Ra) increase with increased feed. Rapid increase is between f =0.2 and 0.41mm (fig.5). It is also clear, that the surface on the sample No. 1 is smooth after machining and this is clearly visible to the naked eye. On the samples No. 3, 4 and 5, the clear

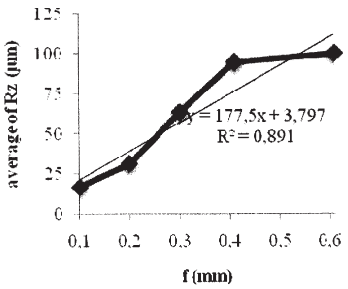

Fig. 5 Dependability of Rz on feeds (linear regression)

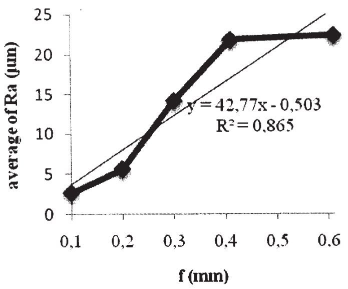

Fig. 6 Dependability of Ra on feeds (linear regression)

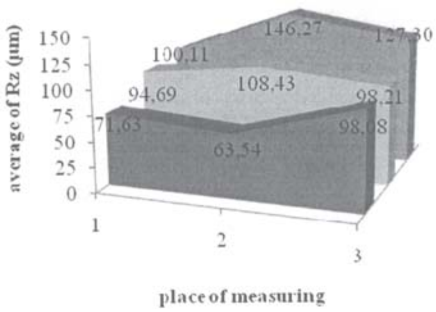

Fig. 7 Comparison of measures values of Rz on samples No. 3, 4, 5 in places 1, 2, 3

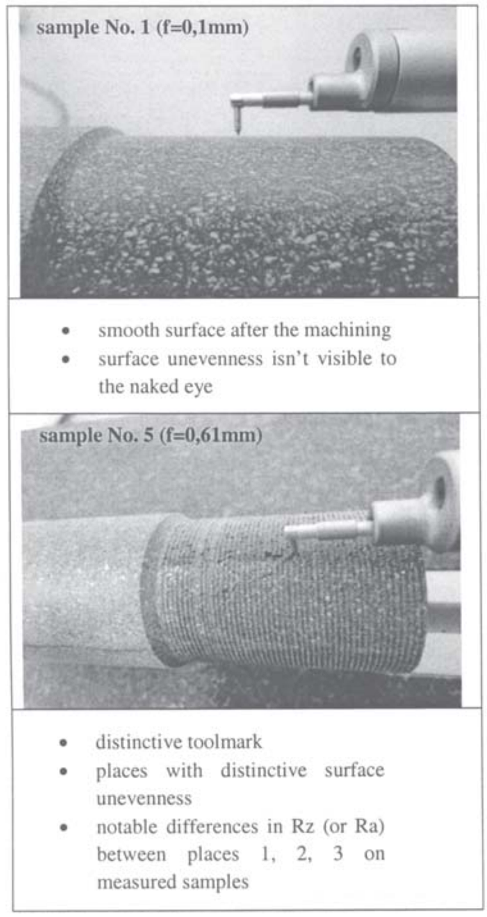

Fig. 8 Sample No. 1 and No. 5 after the turning (f=0,1mm)

toolmark is visible after the machining and also the values of surface roughness are higher (in comparison to samples No. 1 and 2). Figure 7 describes the differences in average maximum height in the particular places – 1, 2 and 3 on samples 3, 4 and 5. High feed of the tool and insufficient encapsulation of wood by plastic caused visible surface unevenness on sample No. 5 (fig.8). The additives (coupling agents such as MAPP – maleic anhydride polypropylene) are used to improve the compatibility of the components – for better interaction between hydrophilic wood and hydrophobic polymer. Due to not knowing the exact composition of the material and the volume of the additives (particularly the volume of the coupling agent or whether the agent was used at all) it is impossible to say that the state of the surface after machining was caused by the lack of the coupling agent. However, based on the results, it is possible to state that the phenomenon did not occur on the samples, which were machined at the lower feeds, or at least the phenomenon was not as visible.

Conclusions

Recommendations resulting from acquired knowledge:

- to select the lower values of feed while machining WPC;
- to select the tool with bigger tool nose radius (the toolmark should not be as visible even at bigger feeds);
- based on the assumption that the WPC material behaves during the machining similarly to wood it is possible to use the tool with bigger tool orthogonal rake;
- application of the tool with linear cutting edge.

This pilot experiment is an initial stage of the research. WPC, as a unique material, requires to be exposed to subsequent detailed investigation for purposes of finding the most suitable alternative for the tool needed for WPC machining (with suitable geometry).

References

1. HREHA, P., HLOCH, S., VALÍČEK, P., MONKOVÁ, K., MONKA, P., HARNIĆAROVÁ, M., FUSEK, M., KONTAJIĆ, P. Technical Gazette, 17 (4), 2010, p. 475
2. FALK, R. H., LUNDIN, T., FELTON, C. Proceedings, Durability and Disaster Mitigation Intended for Outside Applications, 2000, p. 175
3. SIMONSEN, J., FREITAG, G. M., SILVA, A., MORELL, J. J. Holzforschung, 58, 2004, p. 205
4. STARK, N. M., MATUANA, L. M. Polymer degradation and stability, 86, 2004, p. 1
5. PENDELTON, D. E., HOFFARD, T. A., ADCOCK, T., WOODWARD, B. Forest products journal, 52, nr. 6, 2002, p. 21
6. MATUANA, L. M., KAMDEM, D., P., ZHANG, J. Journal of Applied Polymer Science, 80 (11), 2001, p. 1943
7. STARK, N. M., ROWLANDS, R. E. Wood and Fiber Science, 35 (2), 2003, p. 167
8. KLYOSOV, A. A. Wood-plastic composites. J. Wiley & Sons., New York, 2007
9. BUEHLMAN, U., LEMASTER, R., SALONI, D. Proceedings of the 15th International Wood Machining Seminar, 2001, p. 403
10. ADAMCZAK, S., MAKIELA, W., STEPIEN, K. Metrology and Measurement Systems, 17 (2), p. 233

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