Surface quality of Wood Plastic Composite Material after Machining

Zuzana Mitaľová[1], Vladimír Sumkulet[2], Jozef Zajac[3], Svetlana Radchenko[4], Pavel Radič[5], Igor Olexa[6], Juliána Litecká[7]
{zuzana.mitalova@tuke.sk[1], vladimir.simkulet@tuke.sk2, jozef.zajac@tuke.sk[3]}

Technical University of Kosice, Faculty of Manufacturing Technologies with a seat in Presov, Sturova 31, 080 01, Presov, Slovakia[1-3]

Abstract. Presented article is focused on characteristic of WPC (Wood Plastic Composite) and monitoring the effect of variant cutting conditions during technology of milling on result amplitude parameters describing surface topography (Ra and Rz) – after machining of WPC with natural fibers (material is combination of two different phases – the plastic matrix and wood flour, what is material with properties of plastic with wood appearance). Measuring is realized by roughness testers, where have to be consider about inhomogeneity of WPC material (70 % of wood fill and 30 % of HDPE matrix). From the result, the surface roughness is mostly influenced by feed rate.

Keywords: Wood Plastic Composite, milling, surface topography.

1 Introduction

A Wood Plastic Composite are material made up of wood flour (or particles), plastic and additives: lubricants (external – promote slip between a barrel and melting, no sticking between melting and function parts of the extruder and decrease the process temperature, internal – to reduce the shear strength and viscosity of matrix) biocides (protect the organic components against insect attack and fungal fungi), pigments (mainly used for aesthetic reasons (create a character of the surface), coupling agents (used to improve the compatibility of components), flame retardants (are used to reduce a risk of ignition of the product). Natural fiber modifies properties of final material – such as flexural and tensile stiffness (low – cost reinforcement). Wood flour is terms, which means mashed granulates, what appears as flour. Particles are filter by moving by riddles described by US standards. The crushed mixture consists from fibers with the aspect ratio – length to diameter (L/d of particle). This value ranges from 1 to 5. A lower aspect ratio helps to simple transport into the extruder but decreases mechanical properties (a study of Nicole M. Stark and Robert E. Rowland). Matrix is created from plastics (in virgin or recycled form), primary selection of plastics is made following a temperature of processing (T_{max} = 200°C, or some literatures show data – 190°C). PE (polyethylen) is mainly used in different forms (HDPE – High Density PE, MDPE – Medium Density PE, LDPE – Light Density PE) on the other hand, PVC (polyvinilchlorid) and PP (polypropylene) can be used too. Plastics in final product increased weatherability, decay, water resistance and dimensional stability. Additives improve mechanical properties, chemical stability and more easily process (mixing of components). WPC materials represent budged priced of plastics. Traditional materials are displacemented from market, before WPC

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has perfect isolation properties and can be used in building industry. Plastics composite can replace masonry, stone or wood in wall facing. Application of WPC product in industries are in Table 1 [1 – 3].

Table 1. Application of WPC in industry.

Type of industry field	Type of product
Building and construction	Window and door frames, cladding, panels for balconies
Industrial	Industrial and outdoor flooring, railing, bulkheads, pallets
Automotive	Interior panels of car, track floor, roof headliners
Exterior	Decking, fencing, playground equipments, benches
Interior	Bathroom and kitchen furniture, flooring, window boards

The pavilion KIRNU was introduced in exposition EXPO 2010 Shangai in China (the construction materials and methods chosen for the construction are eco-friendly). Teemu Kurkela designed it and pavilion has introduced finland town in miniature. UPM ProFi – WPC composite material was used for facing and produced from recyctable material (paper and plastic). 25 000 injection molded marble white scaly shingles was used for wrapping the outer facade (3700 m^2). This material finds application in common criterias of household. It is possible to find in rooms with water steam (countertops in bathrooms, worktops in kitchens). Terrace coverings, railing systems, balcony panels, claddings profiles are available from WPC products in the Slovakia [4, 5].

Fig. 1. KIRNU shindle close-up [6].

Requirement to increase the lifespan of standard materials from renewable sources is existing. In a process of WPC production wood flour has been used to obtain as by-product in a furniture production eventually recycled plastics. There is no waste generating during the production of profiles, so there is no need to use formaldehyde or some volatiles. Supposition exists that WPC can be machined just like a wood or MDF (conventional woodworking tools).

The uniform density of the products even makes processing easier than with traditional wood products and the net shapes extrusion means that many normal processes are not needed [7, 8].

2 Experimental specification

2.1 Tested material (Wood Plastic Composite – in short WPC)

Wood Plastic Composite with reinforcement from wood with HDPE matrix in ratio 70/ 30 %. Mechanical properties of the composite material were determined in laboratories of VUHŽ Dobrá – Ostrava, Czech Republic. Made in accordance with ISO 6892-1, with a constant load speed of 0.015 mm.s^{-1}, three-point bending test carried out in accordance with ISO 178-1, with constant load velocity of 0.08 mm.s^{-1}.

Table 2. Values of mechanical properties after tensile testing (*probably by reason of the occurance of defects, the test sample 5 was already torn at 200 N, so the result is not mentioned).

Mechanical properties	Average values (measured values from individual samples)
Ultimate tensile strength	19.5 MPa (24/ 15/ 24/ 15/ *)
Elongation at rupture (tensile test)	3.55 MPa (2.5/ 2.9/ 3.4/ 5.1/ *)
Reduction	0.9 % (2.0/ 0.4/ 0.8/ 0.4/ *)
Deformation work	17.6 mJ (20.4/ 12.4/ 24.1/ 13.5/ *)

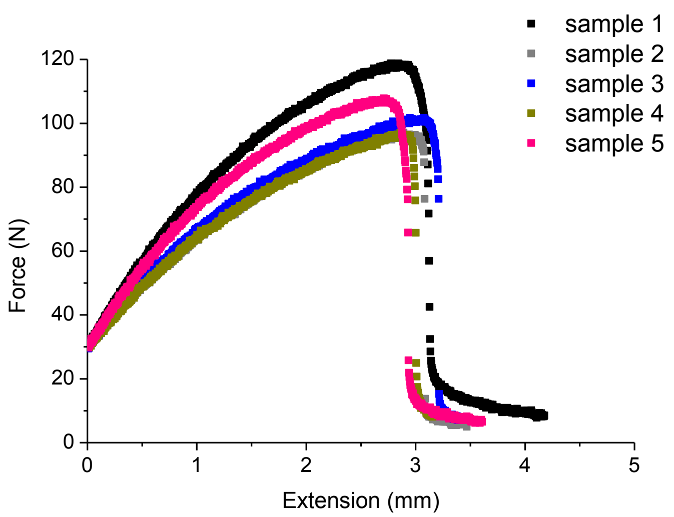

Fig. 2. Three point bending test (average of ultimate bending strength 16.75 MPa, deformation work 0.91 mJ).

2.1 Applied technology of machining (parameters of process, tools and machines)

During the cutting process (milling – CNC milling center Pinnacle VMC-650, clamping by vice milling) were selected of feed rate values in the range from 1000 to 2000 $mm.min^{-1}$ (sample 1: f_1 = 1000 $mm.min^{-1}$, sample 2: f_2 = 1250 $mm.min^{-1}$, sample 3: f_3 = 1500 mm $.min^{-1}$, sample 4: f_4 = 1750 $mm.min^{-1}$ and sample 5: f_5 = 2000 $mm.min^{-1}$), and were set constant depth of cut ap = 2.0 mm and spindle speed n = 1150 $rot.min^{-1}$. Before milling was necessary to realize following steps:

- extruded profile cut by band saw to sample with thickness 80 mm (samples were cut on band saw Bomar type Ergonomic 275.230 DG)
- subsequently mill the samples with parameters described above (for milling of surface end mill FMPCM3063S with 6 teeth and the di-ameter 63 mm was used).

After testing values were created graphical dependences considering with gross errors of surface parameters (Ra – arithmetical profile deviation, Rz – Mean Roughness depth of the profile). Processes of evaluation and measurement have to ensure by reparability of measuring and experiments from the reason of different values of roughness depend on material homogeneity. Roughness parameters were measured in three points (in two lines: first line – LINE 1, middle line – LINE 2) – first is point at the beginning of machining – 10 mm (BEGINNING), second one in the middle of samples – 30 mm (MIDDLE) and the last one at the edge of the testing samples – 50 mm (END – Figure 3). Measuring of the surface texture was realized by using roughness tester Mitutoyo SJ-400 (evaluated length l = 4.0 mm, profile filter λc = 2.5 mm), with measuring repeatability 7 times (in every from three point of LINE 1 and LINE 2).

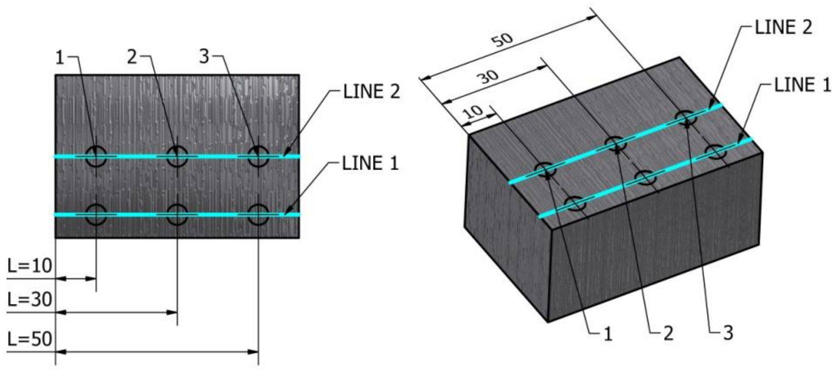

Fig. 3. Principles of measuring and measuring lines (LINE 1 – first line, LINE 2 – middle line).

2 Result of experiment

Table 3 shows the amplitude parameters on individual lines (evaluated as geometrical average from 7 measured values) depend on variant values of feed rate. Subsequently was evaluated overall geometrical average for individual feed rates what is shown in graphical dependences of monitoring surface roughness Rz depend on feed rate: Rz = f (feed rate) mm.min^{-1}. Increasing the feed rate to value f = 1750 mm.min^{-1},causes decreasing of values of the surface roughness Rz and after additional increasing the value of feed rate causes minimal decrease of surface roughness by 2 :m (Table 3).

Table 3. Table of measured values of parameters Rz and Ra (micrometer).

	LINE 1 (first line), parametrs in :m	LINE 2 (middle line), parametrs in :m	Ra, Rz (:m)
Sample	begining/middle/end	begining/middle/end	geometrical average
1	Ra → 4.09/2.73/4.33	Ra → 4.73/6.80/4.17	Ra = 4.32
	Rz → 26.62/19.4/23.36	Rz → 30.81/36.43/26.44	Rz = 26.65
2	Ra → 2.56/2.94/2.51	Ra → 3.25/3.70/3.70	Ra = 3.07
	Rz → 17.83/22.50/21.53	Rz → 19.53/23.24/35.27	Rz = 22.74
3	Ra → 3.20/3.05/4.70	Ra → 3.40/4.59/3.43	Ra = 3.67
	Rz → 17.00/19.51/28.36	Rz → 18.71/28.75/21.54	Rz = 21.86
4	Ra → 2.02/2.35/2.92	Ra → 3.16/3.20/2.75	Ra = 2.70
	Rz → 11.60/13.99/19.97	Rz → 28.80/18.46/19.39	Rz = 17.95
5	Ra → 3.40/2.42/3.83	Ra → 2.84/3.46/3.84	Ra = 3.25
	Rz → 21.14/17.38/20.14	Rz → 16.57/22.79/22.12	Rz = 19.89

Graphical dependences on figures 4 – 8 shown changes of surface roughness values depend on lines (LINE 1 – first line, LINE 2 – middle line). In general can be stated the fact of lower values of selected amplitude parameters are monitored in edge line (near to the perpendicular untouched surface – in LINE 1).

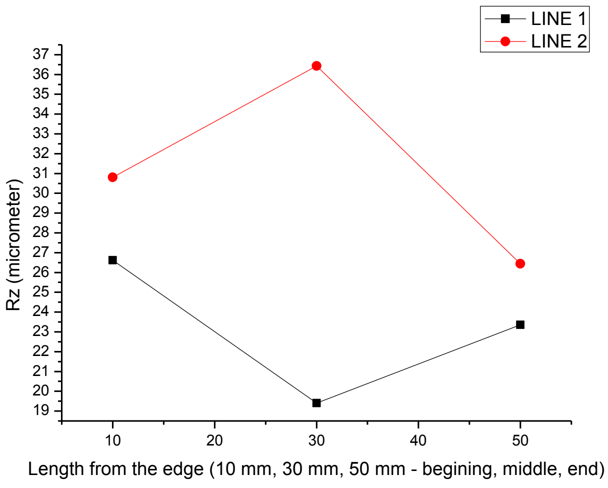

Fig. 4. Graphical dependences of parameter Rz in different lines depend on feed rate (sample 1).

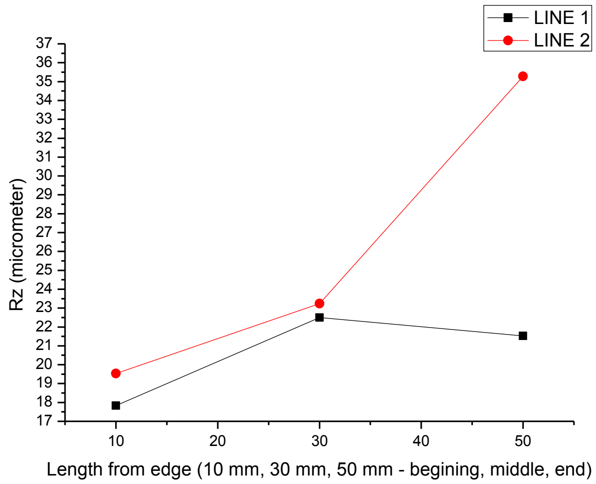

Fig. 5. Graphical dependences of parameter Rz in different lines depend on feed rate (sample 2).

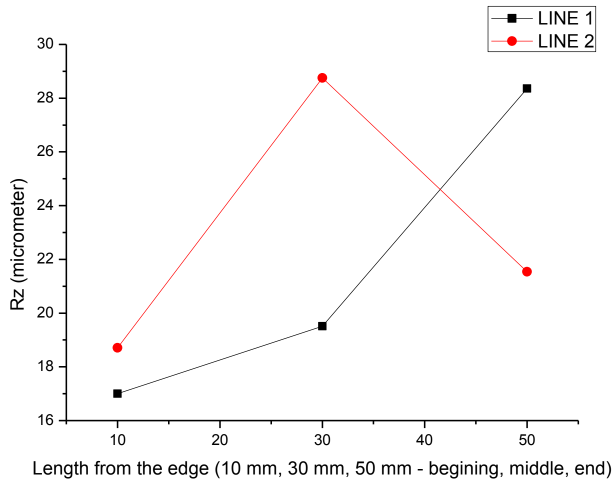

Fig. 6. Graphical dependences of parameter Rz in different lines depend on feed rate (sample 3).

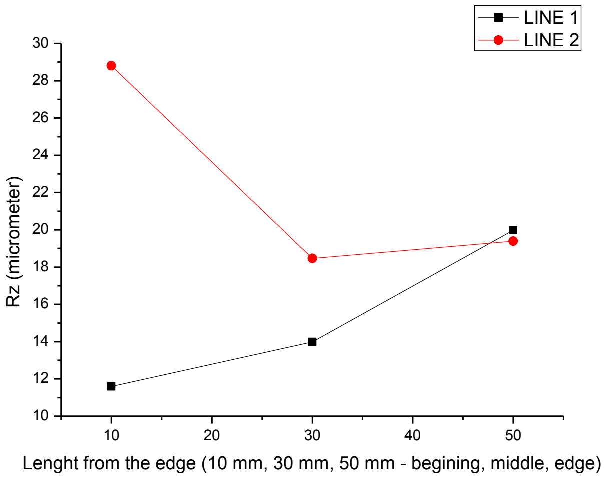

Fig. 7. Graphical dependences of parameter Rz in different lines depend on feed rate (sample 4).

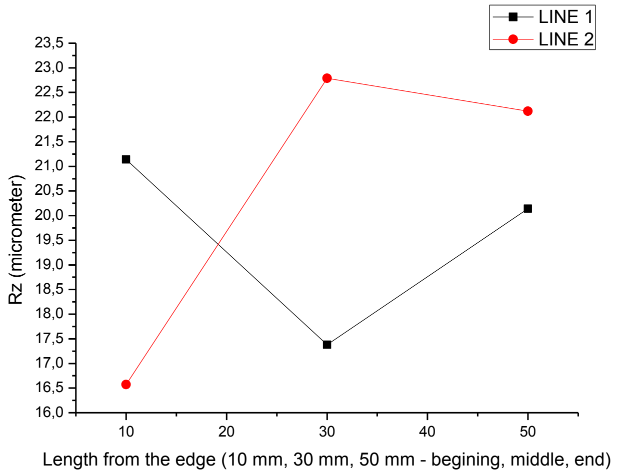

Fig. 8. Graphical dependences of parameter Rz in different lines depend on feed rate (sample 5).

The reason of describing changes in surface roughness can be substantiated by inhomogeneity of material – in the middle of the profile is the homogeneity on the lowest level and to the surface is increasing (in the middle can be seen cracks and holes as see in picture, Fig. 9).

Fig. 9. Image of WPC profile part – material shows microcracks in the area where plastic touches wooden frame (from 20 :m to 4 mm) → inhomogeneity of material (made by Digital Microscope Nicon Eclipse 80i).

Conclusion

Aim of the presented article is to present surface quality of WPC (wood filled plastic) material after chip machining – milling with setting different values of feed rate and constant spindle speed and depth of cut. Increasing the feed rate causes decreasing the surface topography parameters to a limit of 1750 $mm.min^{-1}$. Subsequently were measured lower values of monitoring parameters in the lines nearer to perpendicular sample edge. The behavior of these parameters in individual locations cannot be predicted. The reason is the inherent inhomogeneity of the material – the effect on the machined surface is significant (as is evident from the evaluation of mechanical properties and images of WPC material, too).

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