Study of cutting zone of WPC material after cold cutting

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Abstract. Presented article is focused on monitoring the parameter of the surface integrity after cold cutting. Selected monitoring parameter was surface roughness Ra and Rz in the zone of cutting in three areas specially point of entering, middle part of the workpiece and end of the cutting surface. Experimental material was designed Wood Plastic Composite from the reason of unconventional material and new approach of studying mentioned material to obtain parametrical equation of the surface roughness. Presented article is based on needs from practice and present new scientific sight on material WPC.

Keywords: wood, plastic, composite, cutting zone, roughness.

1 Introduction

Composite materials are materials, which are composed of two and more materials with different characteristic specifications. Term Wood Plastic Composite (WPC) can be to define as composite materials, which is consisting of wood filler and polymer matrix. Wood filler mainly used in application is wood flour from various wood types to achieve reinforcement of thermoplastic matrix. Main advantage is low purchasing costs and low values of density. WPC are biodegradable with possibility to recycle what include them into green materials. Most common thermoplastic polymers used in WPC materials are polyethylene, polypropylene and polyvinylchloride. Combination of wood fillers and thermoplastic can be produced directly designed for selected application. Properties of composite materials can be set by various concentrations of the fillers, matrix and process variables such as temperature, pressure and stir. Manufacturing of the composite materials require

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high demand costs, which are connected on technologies and equipments (form, machine, maintenance and so on). Ration of wood in composite is usually from the range from 30% to 70%. WPC is characterized by higher resistance, less water absorption and higher resistance to molds and fungus. Wood plastic composites do not require additional surface treatment and with wood ration over the 40 % are characterized by higher temperature resistance [3, 7].

Nowadays are WPC mainly used in building industry as replacement of impregnated wood for terraces, railings, wood frames and so on. Currently WPC materials replace components in automotive industry, aerospace industry, electrician industry. Base assumption to achieve required properties is to appropriately choose raw materials[1].

Wood flour is obtained from wood particles from waste products in wood processing industry. Wood mass is from sawmill, furniture, joinery factories and mining in forest and comes in dissimilar sizes, moisture and blended with other substances. Woods flour (Tab. 1)consistency such as flour or sawdust, but can vary in size from fine powder up to the size of a grain of rice. All quality wood flour made from hard wood, because they are durable and strong (Fig. 9). Some flours are made of soft wood such as pine or fir. Wood flour is commonly used as filler in thermosetting resins, such as bakelite, and linoleum[5, 8].

Volume densities of the wood flour depend on several factors – moisture content, particles sizes and wood type. Wood flour is unusual for its compressibility, because during the process temperature and high pressure causes material compression. The value of specific weight is around 1 300 kg • m-3[6].

Wood fibers are cellulose fibers which are obtained from wood, straw, bamboo, cotton seed, hemp, sugar cane and other natural materials. Due to the better mechanical properties compared to wood fiber wood flour it began to use wood fibers for the production of WPC. In general, the higher slenderness ratio, the better the mechanical properties. The physical and mechanical properties of the fibers are depending on the type of wood and the choice is largely influenced by the properties of the final product. The dimensions and the length of wood fibersis quite variable (Tab. 2) [7].

Lignin is a polymer of three-dimensional phenyl propanol which is aromatic and amorphous. Basic building block is phenyl propanol derivatives (ie. P-coumaryl alcohol, coniferyl alcohol, sinapyl alcohol) (Fig. 1). Lignin represents a special glue and the main reason of using lignin is to join the material in the cell wall, which supply appropriate stiffness and strength. The soft wood is 22-33% of wood, but with hardwood, this value is about 16-25%. If we want to produce a quality material, the lignin needs to be removed from the wood [1, 5].

Thermoplastic matrixes used in WPC production have to be characterized by melting temperature under the 200°C from the reason of degradable of the wood particles at temperatures over the 200°C. Currently used thermoplastic matrixes for manufacturing WPC are polyethylene with high density (HDPE), polypropylene (PP) and polyvinylchloride (PVC) [3].

Polyethylene (PE) it is the most produced plastic in the world. It has a relatively low melting point in the range between 106 and 130 ° C depending on the density. PE is produces by the polymerization of ethylene using several possibilities: radi-

cal polymerization or anionic respectively cationic addition polymerization and the ionic coordination polymerization, any of these methods provides a polyethylene with different physical-mechanical properties [4].
Polypropylene or polypropene (abbreviation PP or POP) is a thermoplastic polymer from the polyolefin is used in many sectors including the food industry, textile industry and laboratory equipment. It is sold under the trade names Tipplen, Tatren. Its density is low and is about the value -0.92 0.90 g.cm-3 [3, 6].
Polyvinyl chloride, abbreviated PVC is a plastic polymer made artificially. PVC is a plastic material that is widely used in construction, transportation, electrical - electronic and medical devices, where. PVC is extremely durable and long-lasting construction material, which can be used in various applications, either rigid or flexible. Due to the properties of PVC is used in many sectors, and provides a great deal of popular and necessary products.
Following figure represent percentage ratio of using thermoplastic in the process of manufacturing wood plastic composites (Fig. 2) [2, 4].
Additives used in manufacturing process of WPC materials eliminate deficiency and problems connected with joining two different materials. Adhesion between hydrophobic plastic materials and hydrophilic of wood mass is quite on low level [7, 5].
Reason of use additives:

- Improve conditions during processing,
- Connecting of raw materials, higher level of resistance against biotic and abiotic factors,
- Improve the mechanical and physical properties.

Stabilizers:

- UV stabilizers – absorb UV radiation, which depredate polymers
- Thermo oxidation stabilizes – increase temperature level and time of use.

Biocides:

- Significantly increase degradation of biotic factors, and eliminate grow of fungus and molds.

Polymers modifications:

- Substances that enhance impact resistance and extensibility of the composite.

Plasticizers:

- Volatile organic substances, which affect ductility, flexibility and a reduction in viscosity, increase the thermo-plasticity.

2. Experimental part

Experimental study is based on analyzing of cutting zone after cold cutting technologies (band saw and water jet). Cutting wood composite sample was realized with selected band saw Ergonomic 275.230 DG , which have sufficiently dimensioned drive motor, a gearbox with helical gears and oil fill and a large range of angular cuts from -45 ° to + 60 °. The cutting is ensured by weight arm with hydraulic speed control. Precise hard metal rolling drives of the band saw, joint saw head mounted on tapered roller bearings, a 27mm saw band and synchronized-running brush to remove chips are the prerequisites for excellent cutting performance. Adjustable clamping is designed to prevent the workpiece offices during the process of cutting.

Technical parameters and cutting parameters of the band saw were:

- Minimal cutting diameter ∅ 5 mm, The shortest length of the rest: 20 mm, Material laying height: 760 mm, Blade dimensions (length x height x thickness): 2720 mm x 27 mm x 09 mm, Drive power band: 1.1 / 1.5kW, Saw band speed: 40/80 m.min 1, Total installed power: 2.7 kVA, Dimensions (width x length x height): 640 mm x 1400 mm x 1270 mm
- Cutting condition: Saw band speed: 80 m.min 1, Feed: 0,180m.min-1.

Cutting samples made of WPC realized by water jet were done on machine WJ 3020b – 1 Z (Fig. 3).

Cutting conditions set for the experiment were:

- Cutting speed 100 mm.min-1, Type of abrasive: Australian grenade, Granularity abrasives: MESH 80, Diameter of the nozzle: 0.25 mm, Guidance tube diameter: 1.12 mm, Guidance tube length: 76 mm.

Samples use for the experimental part was selected by various rate of wood manufactured by extruded technology. Individual depositions are shown in the table below (Fig. 4).

To measure the surface roughness of the pre-cut wood composite samples we were used Roughness Mitutoyo SJ 400th

The arithmetic mean deviation of the profile Ra is a height parameter and the average values of the heights and is defined as the arithmetic mean of the heights of the absolute values Z (x) within the regular length lr.

Technical parameters during measuring process were set on following values: Measuring rate: 0.05; 0.1; 0.5; 1.0 mm.s-1; Rate of return of 0.5; 1.0; 2.0 mm.s-1; Measuring direction: backward; Positioning: ± 1,5◦ (slope), 10 mm (up / down); Range / measurement resolution: 800 / 0.01 microns; 80 / 0,001 microns; Supply type: via AC adapter; Evaluated parameters: P (primary), R (roughness), W (filtered waviness); Digital Filter: 2CR, PC75, Gauss; Cutoff length: 0.08; 0.25; 1.8; 2.5; 8 mm. On each sample were measure realized 9 times with calculated mean values for top middle and end of the sample (Tab. 3) with calculated basic statistical indicators and also mathematical equations for each type of cutting as a dependence on wood percentage with correlation index over 95% (1)(2) (Tab. 4).

W – % of the wood

P - % of the plastic

$$Rawj = +0,4241.W^2 - 24,6272.P + 473,5791 \quad (1) \qquad \text{(Water Jet)}$$

$$Ra_{bs} = 0,4946.W^2 - 29,1777.P + 570,5326 \quad (2) \qquad \text{(Band Saw)}$$

Figure 5 (Fig. 5 a) shows comparison of the surface roughness after technological operation water jet and band saw cutting. The graphs have similar curves except that the surface roughness of the cutting band saw is greater than the water jet cutting. Subsequent figure (Fig. 5 b) represent comparison of surface roughness after cold cutting in the zone of the first contact of saw respectively water with workpiece. From the presented results can be stated, that surface affect on technology differently and boundary is 55 %, where individual curves changes their character (increase to rising and convex to concave). From this reason can be set result of the experiment of the use of technology to obtained the best quality surface: Use band saw for materials with wood ratio under the 55% and over mentioned board is supposed to use water jet technology.

3. Conclusion

The charts show the amount of wood% dependence on the arithmetic mean deviation of the profile Ra considered and % dependent on the amount of wood considered the largest height of roughness profile Rz, which were measured using a roughness tester Mitutoyo SJ 400. The comparison of these graphs it can be seen that the% of wood composite wood influences the surface quality.
Surface roughness depends on what kind of cutting materials with which it is used. For sample no. 4 to 50% of the wood is preferable because cutting band saw occurs less rougher surface than with water jet cutting. For samples with no. 5 to 55%, and the sample timber no. 1 with 60% of the wood is better to cut water flow, but the surface arising from the cutting band saw is only slightly higher values. For samples with no.6 with 63% wood sample 2 with 65% of the wood and in a sample of 70% of the wood is better to cut the water jet.

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Figure 1. Structures of the lignin derivates

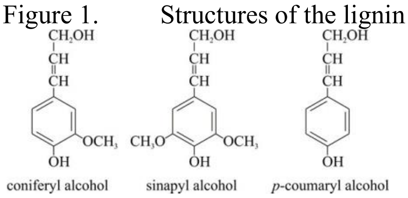

Figure 2. Thermoplastic used in WPC manufacturing

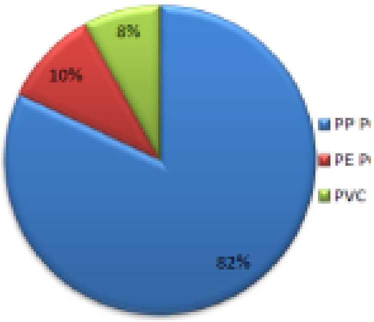

Figure 3. Water jet 3020b – 1Z

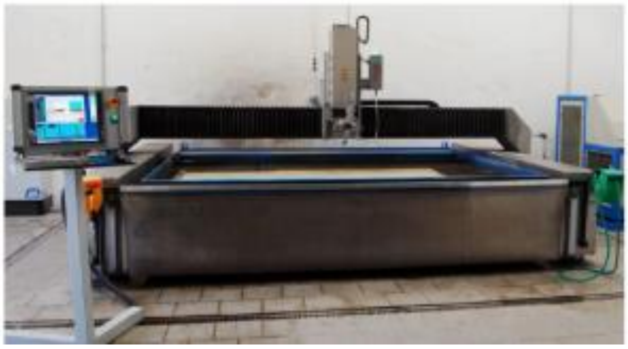

Figure 4. Experimental samples

Sample number	Sample	Composition	Sample number	Sample	Composition
1		Wood 60% Plastic 30 % Additivies 10%	4		Wood 50% Plastic 45 % Additivies 5%
2		Wood 65% Plastic 35 % Additivies 5%	5		Wood 55% Plastic 35 % Additivies 8%
3		Wood 70% Plastic 25 % Additivies 5%	6		Wood 63% Plastic 30 % Additivies 7%

Figure 5. Result of the experiment a) – roughness Ra measured at the end of the samples depend on wood ratio b) – roughness Ra at the beginning of the samples (Red line bend saw; Blue line- water jet)

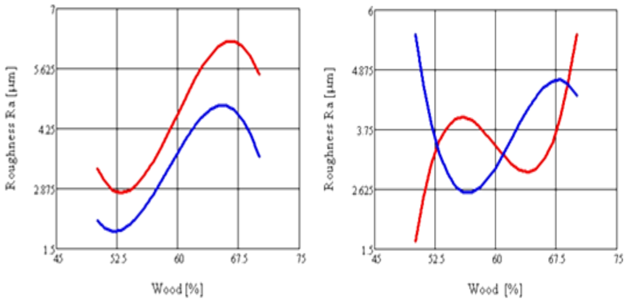

Table 1. Parameters of wood flour

Parameters of wood flour			
Density [kg.m-3]	**Dimensions classes [μm]**	**Ratio length/toughness**	**Humidity [%]**
190-220	50 - 150; 100 - 200; 200 - 450; 250 - 700	2:1 - 5:1	4.VIII

Table 2. Parameters wood fibers

Parameters of wood fibers			
Fiber type	**Density [kg.m-3]**	**Lenght [mm]**	**Diameter [μm]**
Linen	1440	25 - 50	15 - 18
Cotton	1520	15 - 55	10 - 17
Cannabis	1480	15 - 20	15 - 50
Soft wood	1440 - 1550	0,7 - 11	2 - 12
Hard wood	1440 - 1550	0,1 - 7	2 -7

Table 3. Measured values of the surface roughness for the sample 1

METHOD	ROUGHNESS	Place of Measuring	Number of measuring									Mean
			1	2	3	4	5	6	7	8	9	
Water Jet	Ra μm	beginning	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,4	2,38
	Rz μm	beginning	14	14	14	14	14	14	14	14	14	14,06
	Ra μm	end	3,1	3,2	3,2	3,1	3,2	3,2	3,2	3,2	3	3,125
	Rz μm	end	18	18	17	18	18	17	18	18	18	17,65
Band saw	Ra μm	beginning	2,8	3,3	3,3	2,9	3	3,2	2,9	3,3	3,1	3,06
	Rz μm	beginning	18	17	17	18	18	17	18	17	17	17,25
	Ra μm	end	2,9	2,8	2,8	2,8	2,8	2,9	2,8	2,8	2,8	2,81
	Rz μm	end	17	16	17	16	17	17	17	17	17	16,65

Table 4. Statistical indicators

Measuring place	Dispersion	Standard deviation
Beginning WJ	2,23	1,57
End WJ	123	1,11
Beginning BS	1,44	1,2
End BS	2,27	1,5