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Authors: Krzysztof Ciecieląg, Kazimierz Zaleski, Krzysztof Kęcik

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The influence of milling parameters on the surface roughness of glass and carbon fiber reinforced plastics

KRZYSZTOF CIECIELĄG**KAZIMIERZ ZALESKI****KRZYSZTOF KĘCIK ***

* Dr inż. Krzysztof Ciecieląg, k.ciecielag@pollub.pl, <https://orcid.org/0000-0003-1336-0438> – Katedra Podstaw Inżynierii Produkcji, Wydział Mechaniczny, Politechnika Lubelska, Lublin, Polska
 Dr hab. inż. Kazimierz Zaleski, prof. PL, k.zaleski@pollub.pl, <https://orcid.org/0000-0002-3757-3676> – Katedra Podstaw Inżynierii Produkcji, Wydział Mechaniczny, Politechnika Lubelska, Lublin, Polska
 Dr hab. inż. Krzysztof Kęcik, prof. PL, k.kecik@pollub.pl, <https://orcid.org/0000-0001-8293-6977> – Katedra Mechaniki Stosowanej, Wydział Mechaniczny, Politechnika Lubelska, Lublin, Polska

In this paper, the impact of milling process parameters on the roughness of surface of glass and carbon fiber reinforced plastics was analyzed. The influence of feed per tooth, cutting speed and depth of cut on selected surface roughness parameters was determined. It was found that the surface roughness after milling carbon fiber reinforced plastics was greater compared to the surface of glass fiber reinforced plastics.

KEYWORDS: *polymer composites, milling, surface roughness*

Introduction

Roughness is one of the main factors determining the geometric structure of a surface. Of the many roughness parameters, the R_a parameter and R_z parameter (the largest height of the roughness profile) are commonly used in process monitoring [1]. In addition, the R_{sk} parameter associated with surface wear and friction was used [2]. However, based on the value of the R_{ku} parameter, one can conclude about the occurrence of surface defects.

Polymer composites are milled as a finishing machining in order to remove the allowance generated at the manufacturing stage [9]. When choosing the milling parameters, the material structure, orientation and type of fibers as well as the expected surface roughness should be taken into account.

Research works related to the machining of polymer composites with glass fibers focus on the analysis of cutting speed in the range of: $60 \div 250$ m/min [5, 10], feed per tooth: $0.01 \div 0.2$ mm/blade [5] and depth of cut: $0.4 \div 2$ mm [3, 10]. When machining composites with carbon fibers, cutting speeds are used: $20 \div 250$ m/min [4-6, 8], feed per tooth: $0.01 \div 0.5$ mm/cutting edge [5-7, 10] and cutting depth: $0.1 \div 4$ mm [6-8, 10].

Previous work on milling polymer composites has shown that cutting parameters affect the surface roughness in composites with carbon fibers [3]. Variety of results and variables affecting machining quality necessitates the need to examine processes and machinability indicators.

The aim of the study was to determine the impact of speed, feed per tooth and depth of cut during milling of polymer composites with glass and carbon fibers on surface roughness.

Research methodology

The subject of the research were polymer composites with GFRP glass fibers (Fig. 1a) and carbon CFRP (Fig. 1b) impregnated with epoxy resin, in the form of plate with dimensions of $300 \text{ mm} \times 300 \text{ mm} \times 15 \text{ mm}$, made of 50 layers of prepregs with alternating fiber arrangement.

Fig. 1. Processed materials: a) plate with glass fibers, b) plate with carbon fibers

The milling machining process was carried out on a vertical machining center using milling cutters with a diameter of $\varnothing 20$ mm, with replaceable PCD coated inserts intended for machining composite materials, with a corner radius of 0.4 mm and a clearance angle of 15° . The table presents milling parameters adopted in the research.

TABLE. Milling parameters of polymer composites

	v_c [m/min]	f_z [mm/blade]	a_p [mm]
1	50	0.2	1
2	100	0.2	1
3	250	0.2	1
4	350	0.2	1
5	500	0.2	1
6	250	0.04	1
7	250	0.1	1
8	250	0.4	1
9	250	0.6	1
10	250	0.2	0.5
11	250	0.2	1.5
12	250	0.2	2
13	250	0.2	2.5

Each of the tested roughness parameters was measured eight times at different places on the surface of the materials. The smallest and largest measured values were discarded, and then mean values and standard deviations were calculated.

Results

On the basis of determined average values, graphs were made of the relationship between milling parameters and roughness parameters. Figs. 2-5 show the effect of cutting speed on roughness parameters: Ra , Rz , Rsk and Rku .

With an increase in cutting speed in the range from 50 m/min to 500 m/min: the roughness parameter Ra decreased by 23% for GFRP and 46% for CFRP (Fig. 2), the roughness parameter Rz decreased by 15% for GFRP and by 42 % for CFRP (Fig. 3) and the Rsk parameter increased by 44% for GFRP and by 28% for CFRP (Fig. 4). The highest value of the Rku parameter was obtained for a cutting speed of 100÷250 m/min (Fig. 5).

Figs. 6-9 show the influence of feed per tooth on roughness parameters: Ra , Rz , Rsk and Rku . With the increase in feed: the Ra parameter increased by 46% for GFRP and by 84% for CFRP (Fig. 6), Rz parameter by 15% for GFRP and by 70% for CFRP (Fig. 7), as well as the Rku parameter by 23% for GFRP and 72% for CFRP (Fig. 9). The Rsk parameter decreased by 25% for GFRP and by 88% for CFRP (Fig. 8).

Fig. 2. Relationship between cutting speed and Ra parameter

Fig. 3. Relationship between cutting speed and Rz parameter

Fig. 4. Relationship between cutting speed and Rsk parameter

Fig. 5. Relationship between cutting speed and Rku parameter

Fig. 6. Relationship between feed per tooth and Ra parameter

Fig. 7. Relationship between feed per tooth and Rz parameter

Fig. 8. Relationship between feed per tooth and Rsk parameter

Fig. 9. Relationship between feed per tooth and Rku parameter

Figs. 10-13 show the effect of cutting depth on roughness parameters: Ra, Rz, Rsk and Rku. There were no significant changes in the values of roughness parameters as the cutting depth increased.

Fig. 10. Relationship between cutting depth and Ra parameter

Fig. 11. Relationship between cutting depth and Rz parameter

Fig. 12. Relationship between cutting depth and Rsk parameter

Fig. 13. Relationship between cutting depth and Rku parameter

Summary

Based on the results of the research: it can be stated that:

- an increase in cutting speed causes a decrease in the value of roughness parameters Ra , Rz , Rku and an increase in the Rsk parameter: which indicates better surface quality after machining at a higher cutting speed;

- an increase in feed per tooth increases the roughness parameters R_a , R_z and R_{ku} as well as a decrease in the R_{sk} parameter;
- changing the cutting depth does not significantly change the surface roughness parameters;
- due to the possibility of surface defects: low or high cutting speeds (smallest parameter R_{ku}) should be used;
- a significant increase in the R_{ku} parameter as the feed increases the greater likelihood of surface defects after high feed of milling;
- CFRP material is more susceptible to changes in surface roughness caused by an increase in feed and cutting speed compared to the GFRP composite.

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