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EFFECT OF MILLING PROCESS PARAMETERS ON THE SURFACE ROUGHNESS OF CFRP

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Abstract
Carbon fiber reinforced plastic composites possess excellent mechanical properties, and therefore these materials are widely used industries like the automobile, defense, aerospace sectors. However the machining of CFRP materials is difficult, but the mechanical machining of these material is prime requirement to meet dimen- sional accuracy. With showing this problem, the main objective of the present paper is to special solid carbide end mill that are used for milling carbon fiber reinforced polymer composites during trimming, slotting operation. Depth of cut and feed rate are primary cutting parameters that affect the surface roughness. An increase in the depth of cut and feed rate tends to produce a rougher surface due to the increased material removal rate. On the other hand, increasing the spindle speed can decrease surface roughness by reducing the tool's contact time with the work piece. Tool coatings such as DLC (Diamond-Like Carbon) and ALCRN (Aluminum Chromium Nitride) can also affect surface roughness. These coatings have a lower coefficient of friction than uncoated tools, resulting in less heat generation during machining. This reduced heat generation can result in a smoother surface finish. In summary, selecting appropriate cutting parameters and tool coatings can help in achieving the desired surface roughness for a given machining operation.

Keywords: Machining, milling, CFRP, surface roughness, Coating

I. Introduction

Fiber reinforced plastics are among the most high-performance materials in the field of light-weight design due to their ex- ceptional weight-specific qualities. They are especially in- triguing for structural components in the aerospace and space industries due of their high specific strength and stiffness. [1]. Additionally, the use of fibre reinforced plastics is rising in the fields of automotive, medical, and general engineer- ing since they open up new possibilities for product devel- opment and design. [2,3].Although carbon fibre reinforced plastic (CFRP) components are typically produced close to net shape, they must be machined to create bore holes or notches in the workpiece and to enhance the quality of con- tact or functional surfaces. [4]. The process of machining is frequently carried out by milling, drilling, or grinding When compared to metallic alloys, CFRP's machining characteris- tics are fundamentally different, and the cutting mechanism is still mostly understood. [3,5,6,7,8]. The mechanical prop- erties of the CFRP, which are influenced by the kind of fi- bre, the matrix material, the volume of the fibres, the ori- entation of the fibres, and the manufacturing method, have a significant impact on the machinability. It is challenging to identify relationships with broad applicability due to the abundance of affecting elements. Because CFRP is an in- homogeneous and anisotropic material, processing it can challenging due to issues including fibre pull-out, delamina- tion, and matrix material breakdown, which deteriorates the surface quality and material attributes. Thermal impacts have a significant impact on the mechanical characteristics of ma- trix materials in particular. [9]. In contrast, carbon fibres can withstand temperatures of up to 3000°C before the struc- ture starts to degrade In the present study an up-cut milling process of unidirectional CFRP is investigated. Finding a link between the cutting conditions and parameters and the surface integrity of the milled workpiece is the goal of this study. As a result, the workpiece temperature, cutting speed, and fibre orientation have all been adjusted. Cross-sectional micrographs of the specimen are analysed to find probable damages at the machined surface.

II Experimental procedure

Figure 1. Surface Roughness Model

All cutting experiments have been carried out on a three-axis CNC machine BFW make BMV 40 model using a solid car- bide rougher endmill with 18mm cutting diameter. Here using 03 type of solid carbide endmil with same geometry, six flute but varies with DLC coating, ALCRN coating and Un-coated. Helix angle is 30 degree for all solid carbide endmill and shank diameter is 20mm. An milling process was applied under dry conditions to machine a slot into the CFRP specimens. Size of specimen is 125 x 125 x 30 mm. Within the investigations the spindle speed(rpm), feed rate (mm/min) and depth of cut(mm) were varied according to table 1. CFRP specimen clamped on Precision modular vice and Endmill cutter clamped in BT40 Collet Chuck Holder The test setup is shown in figure 2. The Surface Roughness measurement by Mahr make Marsurf PS 10 model (Fig.1)

(1) Solid Carbide End mill , (2) CFRP Material, (3) MillingTool Dynamometer , (4) Precision Modular Vice, (5) BT40 Collet Chuck Holder

Figure 2. Experimental setup used for miling CFRP

Figure 3. Coating end mill

Table 1. Using DLC Coated End mill

SPEED (rpm)	FEED RATE (mm/min)	Depth of Cut (mm)	Surface Roughness (u_m)
1500	250	0.2	0.862
1500	250	0.35	1.993
1500	250	0.5	0.846
2575	350	0.2	1.012
2575	350	0.35	1.965
2575	350	0.5	1.682
4000	450	0.2	1.466
4000	450	0.35	2.626
4000	450	0.5	2.993

Table 2. Using ALCRN Coated End mill

SPEED (rpm)	FEED RATE (mm/min)	Depth of Cut (mm)	Surface Roughness (u_m)
1500	250	0.2	1.105
1500	250	0.35	1.276
1500	250	0.5	0.888
2575	350	0.2	0.993
2575	350	0.35	0.987
2575	350	0.5	1.759
4000	450	0.2	1.033
4000	450	0.35	0.98
4000	450	0.5	0.938

Table 3. Using Un Coated End mill

SPEED (rpm)	FEED RATE (mm/min)	Depth of Cut (mm)	Surface Roughness (u_m)
1500	250	0.2	0.975
1500	250	0.35	0.951
1500	250	0.5	0.983
2575	350	0.2	0.92

2575	350	0.35	0.864
2575	350	0.5	1.111
4000	450	0.2	1.182
4000	450	0.35	1.964
4000	450	0.5	2.003

III Results and discussion

1) Influence of milling parameter on the surface roughness (u_m) by using DLC coated end mill

Based on the given data, we can observe the following trends Surface roughness varies significantly with different combi- nations of speed, feed rate, and depth of cut. In some cases, increasing the depth of cut results in an increase in surface roughness, while in other cases it results in a decrease.

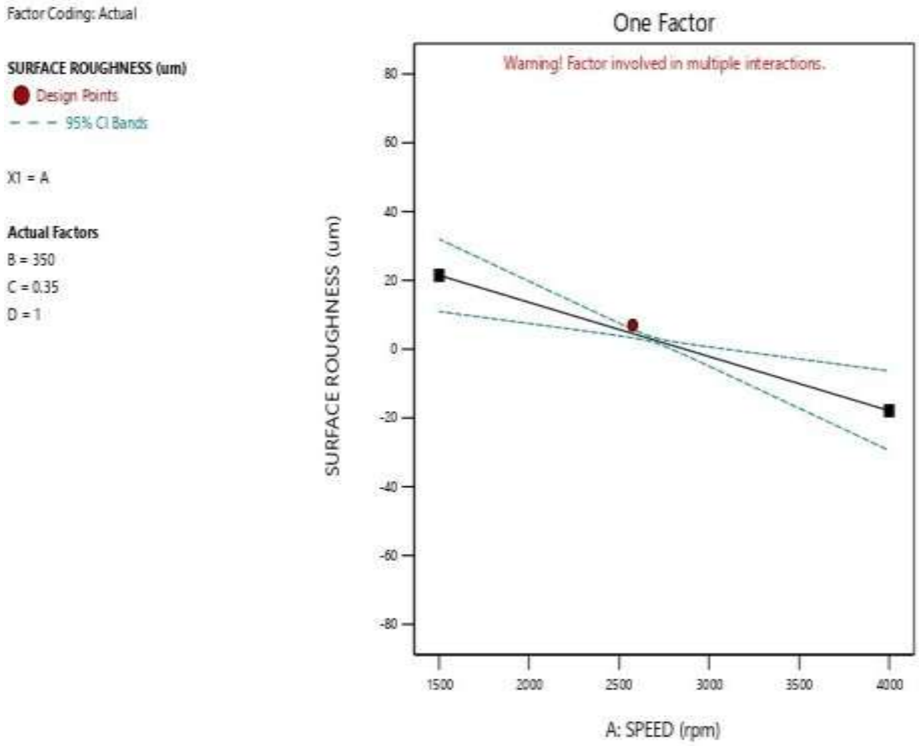

Figure 4. DLC Coating end mill

In general, higher speeds and feed rates tend to produce higher surface roughness, although this is not always the case. To determine the optimal cutting conditions for minimizing sur-face roughness, we can look for combinations of speed and feed rate that produce the lowest surface roughness values for a given depth of cut. For a depth of cut of 0.2 mm, the optimal cutting conditions are at a speed of 1500 rpm and a feed rate of 250 mm/min, which produce a surface roughness of 0.862 um. For a depth of cut of 0.35 mm, the optimal cut-ting conditions are at a speed of 2575 rpm and a feed rate of 350 mm/min, which produce a surface roughness of 1.965 um. For a depth of cut of 0.5 mm, the optimal cutting con- ditions are at a speed of 1500 rpm and a feed rate of 250 mm/min, which produce a surface roughness of 0.846 um. Note that these optimal conditions are based solely on mini- mizing surface roughness and do not take into account other factors such as tool wear, tool life, or machining time. Addi- tionally, the optimal conditions may differ for different types of materials being machined.

2) Influence of milling parameter on the surface roughness (u_m) by using ALCRN coated end mill

To determine the optimal cutting conditions for minimizing surface roughness, we can look for combinations of speed and feed rate that produce the lowest surface roughness val- ues for a given depth of cut.For a depth of cut of 0.2 mm, the optimal cutting conditions are at a speed of 2575 rpm and a feed rate of 350 mm/min, which produce a surface roughness of 0.993 um.For a depth of cut of 0.35 mm, the optimal cut- ting conditions are at a speed of 4000 rpm and a feed rate of 450 mm/min, which produce a surface roughness of 0.98 um. For a depth of cut of 0.5 mm, the optimal cutting conditions are at a speed of 1500 rpm and a feed rate of 250 mm/min, which produce a surface roughness of 0.888 um.

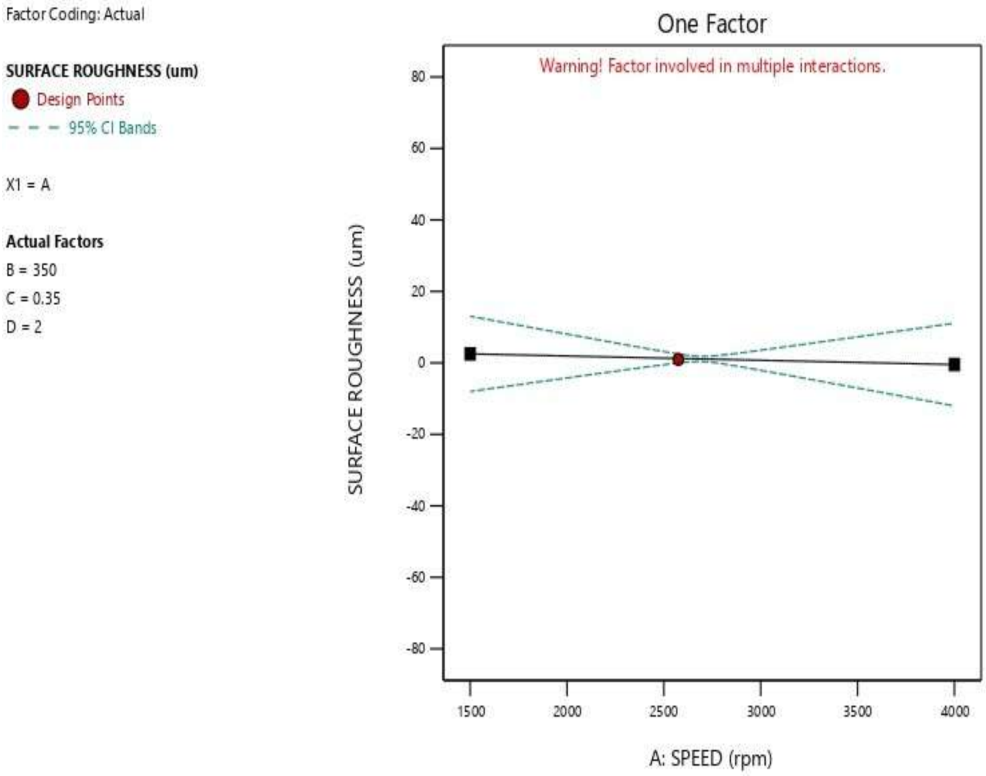

Figure 5. ALCRN Coating end mill

3) Influence of milling parameter on the surface roughness (u_m) by using Un coated end mill

For a depth of cut of 0.2 mm, the optimal cutting conditions are at a speed of 2575 rpm and a feed rate of 350 mm/min, which produce a surface roughness of 0.92 um.For a depth of cut of 0.35 mm, the optimal cutting conditions are at a speed of 1500 rpm and a feed rate of 250 mm/min, which produce a surface roughness of 0.864 um. For a depth of cut of 0.5 mm, the optimal cutting conditions are at a speed of 1500 rpm and a feed rate of 250 mm/min, which produce a surface roughness of 0.983 um.

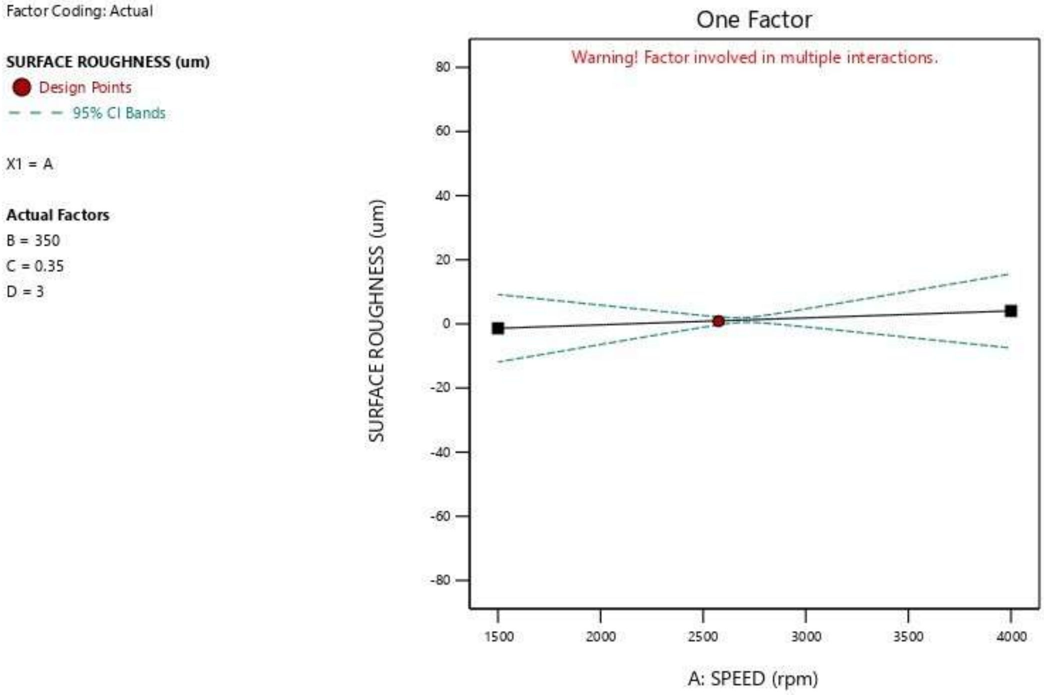

Figure 6. Uncoating end mill

IV Conclusion

The table provided shows the surface roughness produced by different cutting conditions and tool coatings. The cutting conditions are represented by the spindle speed (rpm), feed rate (mm/min), and depth of cut (mm). The tool coatings used are DLC coating, ALCRN coating, and uncoated.

It can be observed that the surface roughness is affected by the cutting conditions and the tool coating. In general, in- creasing the depth of cut and the feed rate tends to increase the surface roughness, while increasing the spindle speed tends to decrease it. Additionally, the DLC coating and the ALCRN coating generally produce smoother surfaces than the uncoated tool.

For example, at a spindle speed of 1500 rpm, a feed rate of 250 mm/min, and a depth of cut of 0.2 mm, the DLC coat- ing produces a surface roughness of 0.862 um, while the AL- CRN coating produces a surface roughness of 1.105 um, and the uncoated tool produces a surface roughness of 0.975 um At a higher spindle speed of 4000 rpm, a higher feed rate of 450 mm/min, and a higher depth of cut of 0.5 mm, the DLC coating produces a surface roughness of 2.993 um, while the ALCRN coating produces a surface roughness of 0.938 um, and the uncoated tool produces a surface rough-ness of 2.003 um

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