Effect of cutter geometrical features for machining polyetheretherketone (peek) using Taguchi methods

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Keywords: Cutter geometrical features; PEEK; Taguchi

ABSTRACT - This study investigate on the effects of cutter geometrical features namely helix angle, rake angle, clearance angle and number of flutes on surface roughness formation for machining Polyetheretherketone (PEEK) material. Statistical Taguchi L_9 and signal to noise ratio were employed to access the relationship between factors and output. From the conducted machining test, it shows that all of the considered factors has significant effect on the surface roughness value.

1. INTRODUCTION

PEEK is a thermoplastic polymer consisted of aromatic ring structure bridging with ketone group and two other linkages which provide toughness, flexibility, and stiffness to the material. The unique characteristics of this material have made it as an alternative for the medical implant to replace metal-based implants such as titanium and stainless steel [1] and it has been applied in the orthopedic section of medical treatment as shown in Fig. 1.

Figure 1 Orthopedic cage made from PEEK [1]

Problems arise when the application necessitate a fine surface which become a challenge for the manufacturer. From the literature, it shows that severe tool wear and rough machined surface were obtained during machining these polymeric materials which closely related with the cutter geometry. Therefore, scientific knowledge on the effect of cutter geometrical features is important for effectively machining PEEK material.

In general, carbide end mill are use to perform the machining process due to the economical and flexibility reasons [2]. Figure 2 depicted in details the nomenclature of the end mill. It can be noted that each of the cutter geometrical features has its own purpose for the cutting process.

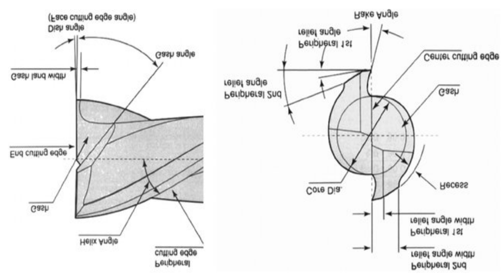

Figure 2 Nomenclature of end mill

Helix angle affects the tool deflection by transferring the stress vertically which allows the tool to produce vertical chip ejection. While rake angle affects the cutting forces, power consumption, chip formation, cutting edge stiffness and rigidity [3]. The stability between the cutting tool and workpiece surfaces are influenced by the tool clearance angle [4]. Indirectly, it affects the tool life. Meanwhile, greater shearing action results in increased speeds and feeds for faster stock removal.

2. METHODOLOGY

Table 1 and 2 show the machining parameters and the design of experiments matrix, respectively.

Table 1 Machining parameters

Spindle speed	4770 rpm
Feed rate	0.05 mm/tooth
Depth of cut	5 mm
Coolant	Dry condition

Table 2 Experimental run

Run	Helix	Rake	Clearance	Flutes
1	20°	5°	6°	2
2	30°	10°	10°	2
3	40°	15°	8°	2
4	20°	15°	10°	3
5	30°	5°	8°	3
6	40°	10°	6°	3
7	20°	10°	8°	4
8	30°	15°	6°	4
9	40°	5°	10°	4

Michael Deckel S20E Turbo CNC tool and cutter grinder machine was used to produce the end mill geometry as in Table 2 prior the slotting test. Upon completion of the slotting process, surface roughness was measured using Mitutoyo SJ-301 portable surface roughness tester.

3. RESULTS AND DISCUSSION

Figure 3 shows the plot graph for the S/N ratio. The best-desired results show the highest S/N ratio, From the graph, it revealed a smaller number of flutes contribute to the highest S/N ratio which indicates a strong relationship on surface roughness formation. The hard-thermoplastic polymer like PEEK required fewer numbers of flutes to provide the greater space for chip ejection and reduce friction at the cutting zone. For the helix angle, too high helix angle increases the friction of the machine surface while too low of helix angle can reduce the shearing action. Thus, the optimum value of the helix angle at 30º is enough to minimize the rubbing between tool and workpiece and provide better shearing action. It also shows that the increasing rake angle value will increase the shear stress which indirectly worsens the surface. Lastly, the clearance angle gives less significant effects on surface roughness.

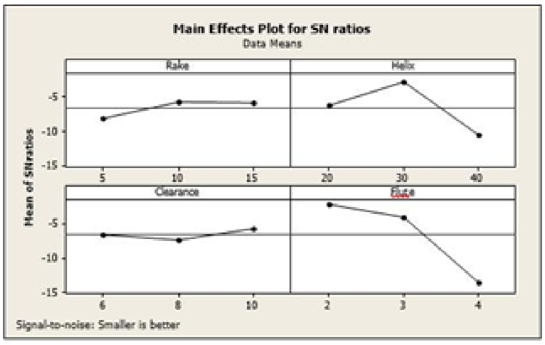

Figure 3 Main effects plot for SN ratio of surface roughness

Table 3 S/N ratio response

Level	Helix	Rake	Clearance	Flutes
1	-6.335	-8.223	-6.728	-2.254
2	-2.954	-5.758	-7.402	-4.119
3	-10.617	-5.925	-5.777	-13.534
DELTA	7.664	2.465	1.625	11.280
RANK	2	3	4	1

Table 3 shows the factor that contributes to the largest effect on the surface roughness value. The number of flutes contributed as the main effect towards surface roughness as changing of the level will give a dramatic change of surface roughness. It followed by helix angle, rake angle and clearance angle.

4. CONCLUSION

From the conducted investigations, it is evident that cutter geometrical features namely rake angle, clearance angle, helix angle and number of flutes have significant effects on machining surface roughness. The number of flutes is the most significant factor that affects the surface roughness value. The findings from the conducted investigation can be use as an input for the development of new cutter design specifically for machining PEEK material.

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