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Research Paper

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Force Analysis in Orthogonal Cutting of GFRP Material

KEYWORDS : GFRP, composite, machining, cutting force,thrust force.

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ABSTRACT

In today's era of composite materials, glass fibre-reinforced plastics (GFRP) composite materials are used in many different engineering applications. The need for machining of GFRP composites has not been eliminated fully.In the presentwork effect of process parameters such as rake angle, feed rate, depth of cut and cutting speed on performance measures of cutting force and thrust force of GFRP material on conventional all geared lathe machine. For the present investigation experiment has been designed with mixed level Taguchi experiment design and analysis of the cutting force and thrust force has been carried out.

INTRODUCTION

Glass fibre reinforced plastics (GFRP) material being used in various fields from aerospace to automotive applications. GFRP materials have attractive properties other than metals and alloys like high strength to weight ratio. They have high corrosion resistance, high fracture toughness and excellent thermal resistance. This are custom made materials and can be prepared according to our requirements. There are different techniques available for preparing GFRP material. In GFRP material main load bearing component is glass fiber and filler material is epoxy resin for this case.

Many researchers have carried out their research on FRP material to study the effect of various process parameters to measure the effect of cutting and thrust force. Koplev carried out orthogonal cutting tests on unidirectional CFRP composite material using a single-edged tool on shaping machine. It has been studied the chip formation process and the machined surface. The tests were conducted when the cut direction was both parallel to and perpendicular to the fibre orientation. A quick stop device was used to examine the chip formation process near the tool tip and in front of it. An innovative facet of this work was the use of the so- called 'macro chip method' to handle and study the many small chips produced by the cutting process.It was reasoned that the cutting force was independent of tool wear as the tool did not cut into the material, and that the increased cutting force was due to the increase in frictional force between the tool and workpiece which in turn was due to the thrust force.

Sakuma and Seto conducted face turning tests on unidirectionally wound GFRP pipes in order to study the effects of fibre orientation on tool wear and cutting forces. It has been observed that chip formation processes similar to those of Koplev, and found that at small fibre angles the fibres were first bent by the progress of the tool and then broken by tension. For large fibre angles, the glass fibres were separated from the cut surface by bending and then broken by shearing. It has been explained the variation in forces obtained during cutting at different fibre orientations as being due to the shear strength of the glass fibre being lower than the tensile strength.

Hocheng et al.conducted milling tests on unidirectional carbon fibre reinforced epoxy material in an attempt to observe chip characteristics and evaluate machinability as a function of fibre direction and cutting conditions. The powder-like chips suggested that the chips were produced by fracture, in keeping with previous observations. Examination of the ribbon-like chips revealed that they were composed of unbroken segments, each produced by fracture with fiber breakage, which were attached by the relatively viscous matrix polymer. The large brush-like chips were produced by delamination at the end of a cut, caused by intralaminar shear.

It was noted that the component of the cutting force parallel to the fibers was less than that orthogonal to the fibers and explained this in terms of the different failure mechanisms described by Koplev. The force required to cause failure of the fibers by buckling is less than that required to cause failure by shear. However, their analysis was qualitative and no attempt was made to predict the forces involved.

Chung-Shin Changconduct experiments and found machinability of high-strength glass fiber reinforced plastics (GFRP) materials in turning with chamfered main cutting edge of P and K type carbide tools. Chip formation mechanisms have been observed with respect to tip's geometries and nose radii. Experimental results for cutting forces were also taken and estimated the empirical constants of the mechanical model and verified its prediction capabilities. The results showed good agreement between the predicted and measured forces. In this study, the nose radius R = 0.3mm induces a decrease of the cutting force and the smallest cutting force values. It was compared the different P and K type of tools, K type tool was better than P type of chamfered main cutting edge tools. The theoretical values of cutting forces were calculated and compared with the experimental results; the forces predicted by this model were consistent with the experimental values.

METHODOLOGY

This section describes the materials and methods used for the processing of the composites under this investigation. Here experimental setup, process and response parameters, and their measuring method discussed in detail. The methodology based on Taguchi experimental design and graphical interpretation of the cutting and thrust forces.

Table 1: Specification of Material

Resin used	Epoxy resin
Fiber orientation	Uniform (
Method of preparation	Pultrusion
Composition	77:23 (Fiber:Resin)
Weight percentage of hardener	5%
Density	2 gm/cm^3
Dimensions	Ø32mm,L=300 mm

Number of machining parameters that effect on material for their various response. The experimentation work on GFRP material have been decided on conventional lathe machine with orthogonal cutting condition. All geared lathe machine available at L.D. College of Engineering, Ahmedabad was used for work. From past literature and availability of machine, levels of process parameters, cutting speed, depth of cut, feed and rake angle have been selected as shown in table2.

Table 2: Parameter selection and their levels.

Symbol	Process parameters	Unit	Level 1	Level 2	Level 3	Level 4
A	Cutting Speed	m/min	19.5	38.6	51.5	80.2
B	Feed	mm/rev	0.047	0.095	0.146	0.19
C	Depth of cut	mm	0.2	0.4	0.6	0.8
D	Rake angle	degree	0	5	NIL	NIL

For the present experimental study k20 series carbide tip tool material has been used and strain gauge type dynamometer has been used to measure the cutting and thrust force.

To design the experiment of the present study, taguchi mixed level orthogonal array has been used and L32 ($2^1 4^3$) orthogonal array has been selected for experiment design.

FIGURE 1: Experimental setup

RESULT AND DISCUSSION

Influence of cutting Speed on cutting force

Figure 2 show that influence of variation in cutting speed on cutting forces during machining of GFRP at various combination levels of feed , depth of cut and rake angle using carbide tip tool. It has been observed that cutting force are increased initially with increasing cutting speed from 19.5 m/min to 51.5 m/min and then start decreasing up to 80.2 m/min of cutting speed.

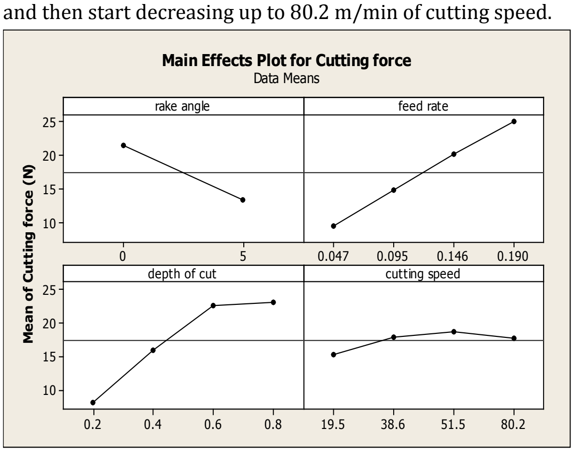

FIGURE 2: Main effect plot for cutting force

Influence of feed on cutting force

Figure 2 show that effect of variation in feed on cutting force observed during machining of GFRP material using carbide tip tool. The cutting force increased with increasing feed from 0.047 mm/rev to 0.19 mm/rev.

Influence of depth of cut on cutting force

Figure 2 show that the influence of the variation in depth of cut on the cutting force during machining of GFRP material with carbide tip too. It is evident that increase in cutting force from 0.2 mm depth of cut to 0.6 mm depth of cut and then it remains steady to 0.8 mm.

Influence of rake angle on cutting force

Figure 2 show that effect of variation in rake angle on cutting force observed during machining of GFRP material using carbide tip tool. The cuttingforce decreased significantly during 5º rake angle compared to 0º rake angle.

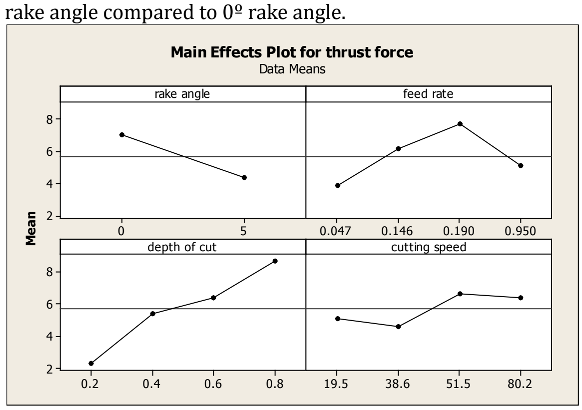

FIGURE 3: Main effect plot for thrust force

Influence of cutting Speed on cutting force

Figure 3 show that influence of variation in speed on thrust forces during machining of GFRP at various combination levels of feed, depth of cut and rake angle using carbide tip tool. It has been observed that thrust force are decreased initially with increasing cutting speed from 19.5 mm/min to 38.6 m/min and then start increasing to 51.5 mm/min and then start decreasing up to 80.2 mm/min of cutting speed.

Influence of feed on cutting force

Figure 2 show that effect of variation in feed on thrust force observed during machining of GFRP material using carbide tip tool. The thrust force increased with increasing feed from 0.047 mm/rev to 0.147 mm/rev and then start decreasing to 0.19 mm/rev.

Influence of depth of cut on cutting force

Figure 2 show that the influence of the variation in depth of cut on the cutting force during machining of GFRP material with carbide tip too. It is evident that increase in cutting force from 0.2 mm depth of cut to 0.8 mm.

Influence of rake angle on cutting force

Figure 2 show that effect of variation in rake angle on thrust force observed during machining of GFRP material using carbide tip tool. The cuttingforce decreased significantly during 5º rake angle compared to 0º rake angle.

CONCLUSIONS

Based on experiments conducted during present course of work, using conventional all geared lathe machine with strain gauge lathe tool dynamometer for studying cutting force, thrust force and affecting machine parameters following conclusion are derived.

- As the rake angle increase cutting force decrease due to ease of material removal.
- As the feed rate increase cutting force increase linearly while thrust force start decrease from 0.19 mm/rev feed rate.
- As the depth of cut increases cutting force increase linearly and gets steady from 0.6 mm. while thrust force increase steadily.
- As the cutting speed increases cutting force and thrust force shows minor change.

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