Experimental Analysis of Surface Roughness and Tool Wear in Machining Process of Glass Fiber Reinforced Plastic Composites

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Abstract

The purpose of the present work is to analyze surface finish and tool wear on Glass fiber–reinforced plastic composites in turning operation faced out by the manufactures. In machining processes, maximum surface finish and less tool wear are important factors influencing the quality of the surface, tool life, and production output. Thus, the selection of tool and optimizing machining parameters are essential for perfect machining. Machining of GFRP material is difficult to carry out due to its anisotropic properties and non-homogeneous structure. The surface finish and tool wear with different parameters viz. speed, feed, depth of cut, fiber orientation and diameter of fiber should be taken very carefully during turning operation to optimize the desirable machining parameters for best quality as well as productivity.

Keywords: *Surface finish; Tool wear; Turning, GFRP; Machining Parameters.*

INTRODUCTION

GFRP composites are extensively used in automobile, aerospace and marine applications because of their high specific strength, high specific stiffness, better impact characteristics, corrosion resistance and design flexibility. Machining of GFRP material is difficult to carry out due to the non-homogenous structure of material. Several authors studied the effect of process parameters on tool wear for different work materials. However, studies on tool wear in GFRP are not widely available in literature [1].

Fiberglass composites are an economical alternative to stainless steel and other materials in highly corrosive industrial applications. In recent years, glass fiber reinforced polymers (GFRP) have been extensively used in variety of engineering applications in different fields such as aerospace, oil, gas and process industries[2]. GFRP composite components are normally fabricated by processes such as filament winding, hand lay-up, etc. After fabrication, they require further machining to facilitate dimensional control for easy assembly and for functional aspects. The machining of GFRP composites is different from conventional materials. The behavior of composites is anisotropic [3]. The quality of machined products depends upon the fibers, matrix materials used, bond strength between fiber and matrix, type of weave, etc. [4]. The first theoretical work on FRP was presented by Ever tine and Rogers. They did the theoretical analysis on plane deformation of incompressible composites reinforced by strong parallel fibers [5]. It carried out a study on machining of polymer composites. They concluded that higher cutting speeds give the better surface finish. Takeyama and Lijima studied the surface roughness on the machining of GFRP composites [6].

According to them, higher cutting speed produces more damages on the machined surface. This is ascribable to higher cutting temperature, which results in local softening of work material. They also studied the machinability of FRP composites using the Ultrasonic machining technique [7]. At the point when GFRP composites are machined, it is obviously observed that the filaments are cut crosswise over and along their lay course, leaving disfigured projections and somewhat revealed strands on the machined surface. According to Konig, estimation of surface unpleasantness in FRP is less reliable than in metals, on the grounds that jutting fiber tips may prompt erroneous results [8]. Extra mistakes may result from the snaring of the strands to the stylus. Ordinary machining of fiber-fortified composites is troublesome because of different fiber and network properties, introduction, inhomogeneous nature of the material, and the nearness of high-volume portion (volume of fiber over aggregate volume) of hard rough fiber in the matrix [9].

The majority of the outcomes on GFRP composite machining demonstrate that limiting the surface unpleasantness is extremely troublesome and it must be controlled. The machining of fiber-strengthened materials requires extraordinary contemplations about the wear obstruction of the apparatus. High Speed Steel (HSS) isn't appropriate for cutting attributable to the high component wear and poor surface wrap up. Consequently, carbide and precious stone instruments are utilized as reasonable cutting apparatus materials Surface unpleasantness assumes a critical job in numerous zones and is a factor of awesome significance in the assessment of machining accuracy [10]. The surface unpleasantness of a machined item could influence a few of item's useful properties, for example, contact causing surface erosion, wearing, light reflection, warm transmission, the capacity to disperse and holding an ointment, covering and opposing weariness. Keeping in mind the end goal to get great surface quality and dimensional properties, it is important to utilize improvement methods to discover ideal cutting parameters and hypothetical models to do forecasts. Taguchi and response surface methodologies can be conveniently used for these purposes [11]. The response surface method and genetic algorithm for predicting the surface roughness and optimizing the process parameters. Taguchi and response surface methodologies for optimizing geometric errors in the surface grinding process. The response surface method (RSM) is more practical, economical and relatively easy to use. In the present study, the effect of cutting parameters on surface roughness on the machining of GFRP composites by carbide tool is evaluated and second-order model is developed for predicting the surface roughness[12]. The primary focus of this research work is to analyse effectively to predict the desirable machining parameters especially, surface roughness in the machining of GFRP composites.

EXPERIMENTAL MATERIALS

GFRP-Glass Fibre Reinforced Plastic and the material was produced by pultrusion method with epoxy resin and E-glass. It has 82.27% glass contents. GFRP rods produced by pultrusion method are used in this study. The diameter and length of the specimen are 40 and 280mm, respectively having an L/D ratio 7, which were used for the experiments. The work piece was turned for 90mm in all the trials.

MACHINING PROCESS

The equipment used for turning consists of a Kirloskar centre lathe turning machine with 3 Hp/2.2 kw DC compound motor. GFRP-Glass Fibre Reinforced Plastic The material was produced by pultrusion method with epoxy resin and E-glass. It has 82.27% glass contents. Specific weight (g/cm^3)2.5,Tensile strength (N/mm^2)

1800,Young's modulus (N/mm^2)7400, Thermal coefficient of expansion (α)5, Thermal conductivity (w/m-k) 0.8, Glass fiber E – glass, Matrix material epoxy resin.

The composite specimens are 350 mm in length, with 40 mm diameter, respectively, AKIRLOSKAR CENTRE LATHE turning machine with 3 HP/2.2 KW DC COMPOUND MOTOR was used to perform the machining operation. The carbide tool inserts are coated by tungsten carbide with the series of SNMG 120408 is used for the machining are of readily available. The geometry of the cutting tool insert is as follows: rake angle −7° (negative), 7° clearance angle, 80° edge major tool cutting, 0° cutting edge inclination angle, and a nose radius of 0.8 mm.

DESIGN OF EXPERIMENTS

Identification of Parameters

The factors that influence the output response are identified, before conducting the experiment. The tool wear, surface roughness, chip thickness and chip length are the output responses that are to be measured. The factors that affect the response are identified based on the experience. The following are the parameters which affect the tool life: Cutting speed(S), Feed rate (F), Depth of cut (D) Of the above parameters, taking the characteristics of tool wear into consideration the following are considered as primary factors for this study.

Cutting speed(S) Feed rate (F) Depth of cut (D) Temperature (T) Tool Wear (TW).

Selection of Orthogonal Array

The L27 orthogonal array is formed, computation of variation for the L27 orthogonal array is formed using Taguchi's design of experiment concept. Each and every control factor fits into the table and the computation of S/N ratio is done to find the optimum condition among various experimental conditions with different parameter combination. Both the methods are checked with the help of classical analysis of variance (ANOVA)

Optimization of Parameters using Taguchi's Technique

The essential step of Taguchi method is to identify the important parameters, which affect the process. From the literature and the previous work done in this field the independently controllable predominant machining parameters, which have greater influences on the machining of GFRP composites are identified and tabulated below:

Taguchi experimental analysis was made using the popular software specifically used for the design of experiment applications known as MINITAB 15. The predicted optimum is used to find the optimum value in mechanical testing.

Table: 1. *L27 Orthogonal Array*

TEST RUN	X1	X2	X3	V	F	D
1	1	1	1	50	0.10	0.4
2	1	1	2	50	0.10	0.8
3	1	1	3	50	0.10	1.2
4	1	2	1	50	0.15	0.4
5	1	2	2	50	0.15	0.8
6	1	2	3	50	0.15	1.2
7	1	3	1	50	0.20	0.4
8	1	3	2	50	0.20	0.8
9	1	3	3	50	0.20	1.2
10	2	1	1	75	0.10	0.4
11	2	1	2	75	0.10	0.8
12	2	1	3	75	0.10	1.2
13	2	2	1	75	0.15	0.4

14	2	2	2	75	0.15	0.8
15	2	2	3	75	0.15	1.2
16	2	3	1	75	0.20	0.4
17	2	3	2	75	0.20	0.8
18	2	3	3	75	0.20	1.2
19	3	1	1	100	0.10	0.4
20	3	1	2	100	0.10	0.8
21	3	1	3	100	0.10	1.2
22	3	2	1	100	0.15	0.4
23	3	2	2	100	0.15	0.8
24	3	2	3	100	0.15	1.2
25	3	3	1	100	0.20	0.4
26	3	3	2	100	0.20	0.8
27	3	3	3	100	0.20	1.2

***Table: 2.** Machining Parameters and Levels*

Control Parameters	**Unit**	**symbol**	**Levels**		
			Level 1	**Level 2**	**Level 3**
Cutting speed	m/min	V	50	75	100
Feed	mm/rev	F	0.10	0.15	0.20
Depth of cut	mm	D	0.4	0.8	1.2

RESULT AND DISCUSSION

The S/N ratio for Ra and Fw is computed using the following equation and corresponding values are shown in the table.

***Table: 3.** Optimization of Machining Parameters*

EXPERIMENT NO	**CUTTING SPEED (V)**	**FEED (F)**	**DEPTH OF CUT (D)**	**SURFACE ROUGHNESS (Ra)**	**FLANK WEAR (Fw)**
1.	50	0.10	0.4	3.59	0.018
2.	50	0.10	0.8	3.20	0.025
3.	50	0.10	1.2	3.70	0.040
4.	50	0.15	0.4	2.71	0.025
5.	50	0.15	0.8	3.66	0.031
6.	50	0.15	1.2	3.53	0.045
7.	50	0.20	0.4	2.94	0.032
8.	50	0.20	0.8	3.16	0.039
9.	50	0.20	1.2	4.67	0.076
10.	75	0.10	0.4	2.82	0.024
11.	75	0.10	0.8	2.77	0.032
12.	75	0.10	1.2	2.52	0.044
13.	75	0.15	0.4	2.33	0.029
14.	75	0.15	0.8	2.39	0.036
15.	75	0.15	1.2	2.62	0.051
16.	75	0.20	0.4	2.57	0.044
17.	75	0.20	0.8	4.62	0.047
18.	75	0.20	1.2	4.26	0.064
19.	100	0.10	0.4	3.47	0.029
20.	100	0.10	0.8	3.68	0.039
21.	100	0.10	1.2	3.61	0.057
22.	100	0.15	0.4	3.76	0.046
23.	100	0.15	0.8	3.62	0.053
24.	100	0.15	1.2	2.63	0.067
25.	100	0.20	0.4	3.59	0.081
26.	100	0.20	0.8	3.73	0.096
27.	100	0.20	1.2	3.61	0.108

The formula for ANOVA Table

SS Fiber = $A12nA1$+ $A22nA1$+⋯+ $An2nAn - T2N$

SS Total = each strength2 – $Sumofstrengt$h227
SS e-pool = SS Total – sum of other sequence
DOF fiber = No. of levels -1; = 3 -1; = 2
DOF Total = No. of runs – 1; = 27 – 1; = 26
DOF e-pool = DOF Total – sum of other DOF = 26 – 8 = 18
Mean sq. = $Sumofsquaresduetoeac$h $factorDegreesoffreedomforeac$h $factor$
Variance ratio = $MeansquaresduetothefactorMeansquareserror$
Percentage of Contribution = $Sumofsquaresforeac$h $factor$ ×100$Totalsumofsquares$

Table: 4. *Percentage of Contribution*

Source of Variation	**Sum of Square**	**DOF**	**Mean Square**	**Variance (F)**	**Percentage (%)**
Cutting speed	0.4903	2	0.2451	0.5500	4.6196
Feed	1.0957	2	0.5478	1.2293	**10.323**
Depth of cut	0.1141	2	0.0570	0.1280	1.0753
Error	8.9138	20	0.4456	1	83.981
Total(T)	10.614	26	0.4082	0.9159	100

The ANOVA for Penetration. The last column of the table indicates that all have very small p values. Cutting speed (v= 4.6%), Feed (f = 10.32%), Depth of cut (d =1.07 %), e-pool (p= 83.98%) have great influence on penetration. The maximum percentage of contribution is Feed = 10.32%. The percentage of contribution in E-pool is = 83.98 %. The feed is the dominant parameter for surface roughness followed by the cutting speed. The depth of cut shows a minimal effect on surface roughness compared to other parameters.

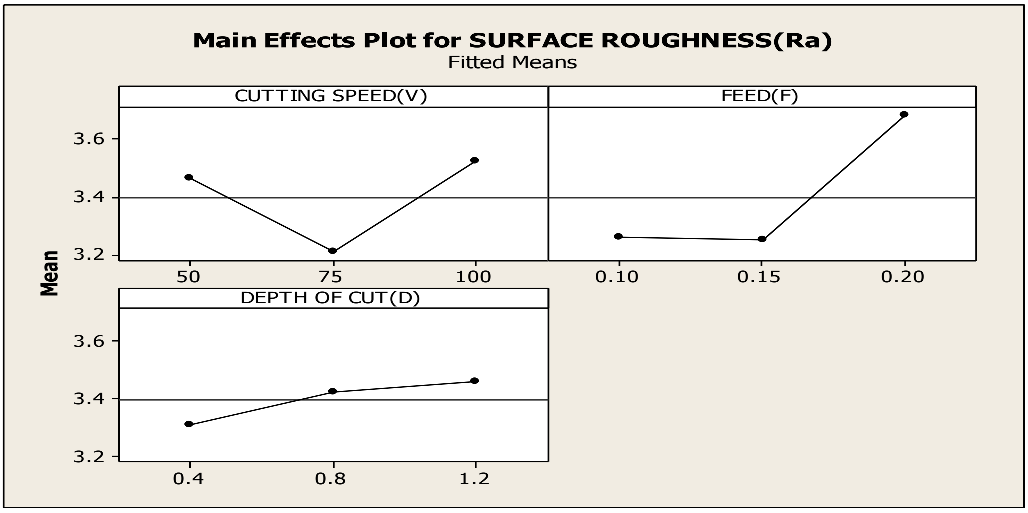

Fig: 1. *Interaction Plots For Means of Surface Roughness vs. Parameters*

Interaction graph was plotted between means of surface roughness and various parameter levels. Fig 4.3 shows this interaction plot. When cutting speed increases, the mean value of surface roughness decreases to a cutting speed of 75 m/ min and then increases gradually. At 75 m/min of cutting speed minimum value of surface roughness was obtained. When feed increases, the mean value of surface roughness constant up to 0.15 mm/rev and then increases rapidly. At 0.15 mm/rev I obtained the minimum value of surface roughness. When a depth of cut increases surface roughness gradually increases. At 0.4 mm of the depth of cut minimum surface roughness value was obtained.

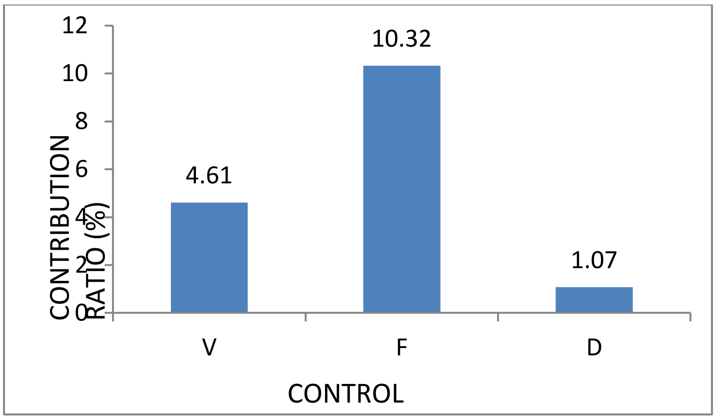

Fig: 2. *Pareto Diagram for surface roughness*

Depicts the Pareto diagram for surface roughness, the significant factors are chosen from the left-hand side in the Pareto diagram from this diagram feed rate is Identified as the significant factor of affecting the surface roughness. Feed rate should be reduced to decrease the surface roughness.

Table: 5. *ANOVA table for flank wear*

Source of Variation	Sum of Square	DOF	Mean Square	Variance (F)	Percentage (%)
Cutting speed	0.0038	2	0.0019	24.29	29.59
Feed	0.0046	2	0.0023	29.31	35.71
Depth of cut	0.0029	2	0.0114	18.46	22.49
Error	0.0015	20	7.9011	1	12.18
Total(T)	0.0129	26	0.0004	6.313	100

The ANOVA for Flank Wear. The last column of the table indicates that all have very small p-values. Cutting speed (v= 29.59%), Feed (f = 35.71%), Depth of cut (d =22.49 %), Error is (p= 12.18%) have great influence on penetration. The maximum percentage of contribution is Feed = 35.71%. The percentage of contribution in Error is = 12.18 %.

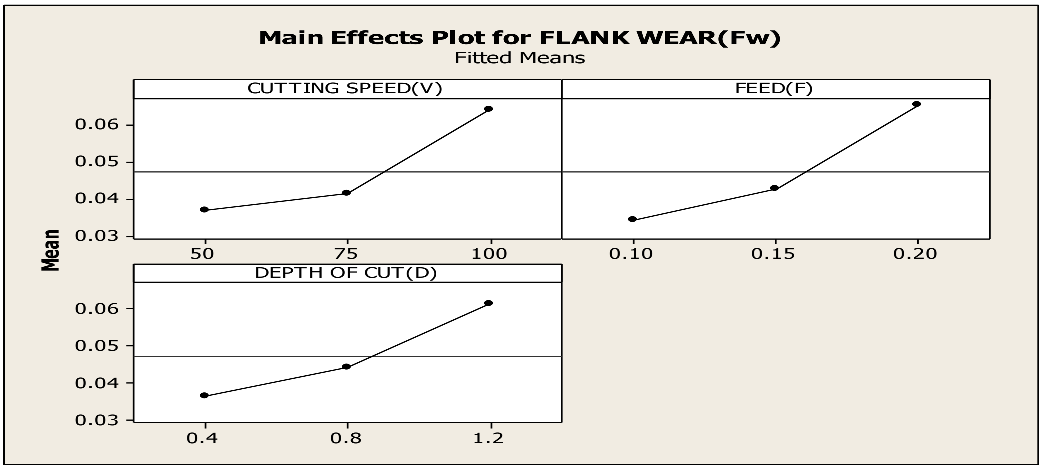

Fig: 3. *Interaction plots for means of flank wear vs. parameters*

Interaction graph was plotted between means of flank wear and various parameter levels. Fig 6.3 shows this interaction plot. When cutting speed increases, the mean value of flank wear increases to a cutting speed of 75 m/min and then increases rapidly. At 50 m/min of cutting speed minimum value of flank wear was obtained. When feed increases, the mean value of flank wear increases up to 0.15 mm/rev and then increases rapidly. At 0.1 mm/rev, I obtained the minimum value of flank wear. When the depth of cut increases surface roughness gradually increases. At 0.4 mm of a depth of cut minimum flank wear value was obtained.

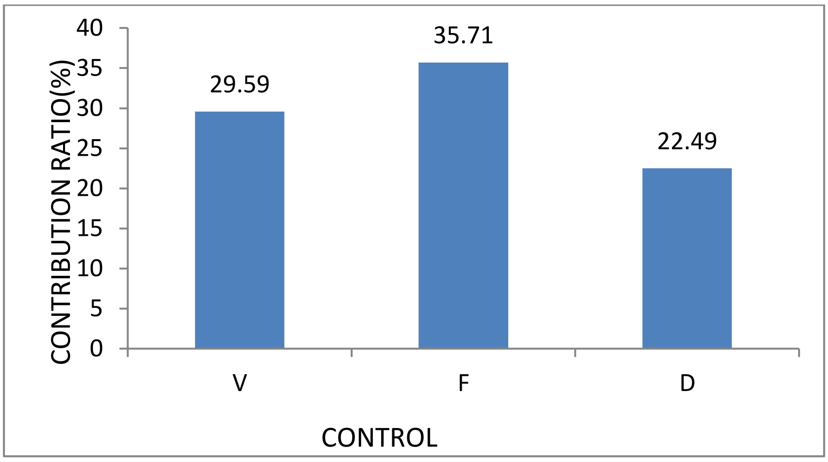

Fig: 4. *Pareto Diagram for flank wear*

Depicts the Pareto diagram for tool wear, the significant factors are chosen from the left-hand side in the Pareto diagram from this diagram feed rate is identified as the significant factor of affecting flank wear. Feed rate should be reduced to decrease the flank wear.

Based on to the above experiments and analysis for Surface roughness the optimized results obtained are, Cutting speed 75 m/minified rate 0.15 mm/rev, Depth of cut0.4 mm
for flank wear the optimized results obtained are Cutting speed 50 m/min,
Feed rate 0.10 mm/rev, Depth of cut 0.4 mm.

CONCLUSION

Based on the performance and the test result of the various set of experiments analyzed to influence the different machining parameter on the machinability characteristics on GFRP during turning operation with tungsten carbide tool with a dry run condition. This research work concluded that cutting speed-75 m/min, feed rate- 0.15 mm/rev, depth of cut- 0.4mm will provide optimum surface roughness. In case of flank wear feed rate is a dominant parameter and to followed by the cutting speed. The depth of cut shows the minimal effect on flank wear compared other parameters and it also indicated that cutting speed-50 m/min, feed rate- 0.10 mm/rev, depth of cut- 0.4mm will provide an optimum result. For achieving good surface finish and productivity on the GFRP work piece, high cutting speed, high depth of cut and lower feeds are preferred.

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