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# An Experimental Investigation of Surface Roughness And Cutting Forces On GFRP

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**Abstract:**

In the current study, the emphasis was on finding experimental results on machinability of Glass fibre reinforced plastic composite with milling machine. Study is carried out with objectives of examination of cutting parameter on GFRP materials. Speed , feed, depth of cut & number of flute are consider for analyzing effect on surface finish & cutting forces of composites. Design of experiment is carry out by Taguchi's L18 orthogonal array. To find out more about the machining parameters on GFRP composite using end mill of cemented carbide, an analysis of variances (ANOVA) utilizing Minitab 15 software was finally carried out.

**Keywords:** GFRP, ANOVA, cutting forces, surface roughness.

## 1. Introduction

Now a days , due to their improved qualities, Composites materials have been seriously examined to replace traditional materials for a variety of applications, including those in the aerospace, transportation, defense, house hold application, structural and sports industries .On account of their appealing mechanical and physical properties make them as an attractive option for manufacturer. properties possesses by Glass fiber reinforced plastics like high specific stiffness, light weight and higher strength makes it suitable in aerospace and aircraft industry. Many times machining of composite makes it's difficult because of fabrication of composite materials, anisotropy, non-homogenous structure of composites and also reinforcement in matrix while fabricating it.

Many authors studies on milling machine of glass fibre reinforced plastic and have find out that delamination and quality of surface is prominently depends on forces , geometry of tool & machining specifications . Surface roughness is an attribute that can affect production costs, mechanical product performance, and dimensional accuracy. Likewise there should be less cutting forces produced while milling GFRP composite. In order to reduce cutting forces & surface finish, research and development have been conducted in order to optimize cutting characteristics.

In order to reduce cutting forces and surface finish of composite materials, this research examines the effects of milling machine machining parameters like feed, number of flutes, cutting speed & depth of cut.

## 2. EXPERIMENTAL DETAILS:

Composite of glass fiber-reinforced plastic utilized in this experimental investigation as demonstrated in Fig.1, were fabricated by hand layup method is supplied by Polyplast Chemi Pvt.Ltd. Thane (W). In this experiment, GFRP composite fabricated with dimensions 150 × 120 × 12 mm thick are used. Rectangular specimen of GFRP has the combination of glass fibre and epoxy resin. The experiment have been carried out on GFRP composite material by using end mill (K10) of cemented carbide of 10 mm diameter was displayed in Fig.02. A CNC milling machine with spindle speed of 4000 rpm was employed in trail runs. The composite material is fixed using a dynamic tool to measure the cutting forces and Ensure that displacement and vibration have been removed. For measurement of cutting force components during milling operation KISTLER make cutting force dynamometer with built-in charge amplifier with control unit type 5233A was used to acquire the 3 orthogonal like Fx , Fy & Fz. Forces were directly measured using Dynoware Software installed in computer. A portable surface roughness tester was used to measure the machined surface's surface roughness.(Mitutoyo, Japan makes).

FIG.1 GFRP component

FIG.2 Cemented carbide end mill

## 3. EXPERIMENTAL PLAN

The study carried out to assess the influence of machining and process parameters related to cutting tools on the GFRP composite of a milling machine. To assess the influence of parameters associated with tools and machining on the forces of cutting and surface roughness, statistical experiments utilizing Taguchi design were conducted. Design of experiment is a systematic way to find various combinations of process parameters to obtain robust process performance. A robust design of Taguchi’s orthogonal array for varying levels of three different factors & one factor at two levels are choose to perform experimental plan. The Factor and their levels are shown in Table 1. The array L18 was selected for the experimentation. ANOVA was carried out to find out the influences of machining parameters on surface finish & cutting forces.

**Table 1** Factors and their levels

| Sr.No. | Factor | Levels | | |
|---|---|---|---|---|
| 1 | No. of flute | 2 | 4 | |
| 2 | Cutting speed (m/min) | 50 | 100 | 150 |
| 3 | Feed (mm/rev) | 0.04 | 0.08 | 0.12 |
| 4 | Depth of cut (mm) | 0.5 | 1 | 1.5 |


**Fig.3.** Photograph of KISTLER dynamometer (a) Control box and (b) GFRP composite mounted on dynamometer

Fx, Fy, and Fz , cutting forces during machining in x, y & z directions was displayed in Fig. 3 (a) measured using Kistler 3-Component dynamometer. Fig 4 (a & b) show the surface roughness tester used while taking the reading of roughness of composite.

**Table 2.** Specifications of SJ 301 surface roughness tester are as follows:

| Parameter | Ra |
|---|---|
| Filter | 2R-C Type |
| Cut off length | 0.08, 0.25, 0.8, 2.5 mm |
| Resolution(Vertical) | 0.01µm |
| Tip radius | 5 µm, 2µm |
| stylus material | Diamond |
| Radius of Skid curvature | 40mm |

Fig.4 (a) Surface Roughness Tester

(b) GFRP composite while testing

Hand layup made was used to fabricate the glass fibre reinforced plastic composite. Milling machine was used to identify the machinability of composite material by using end mill cemented carbide tool. Machinability of composite was calculated through considering surface roughness and cutting force of machining. After conducting experiments on fabricated GFRP composite materials, experimental values of surface finish and cutting forces were mentioned in Table 03.

| Experiment No. | Input parameter | | | | Output parameter | | | |
|---|---|---|---|---|---|---|---|---|
| | Flute | Cutting speed | Feed speed | Depth of cut | Fx (N) | Fy(N) | Fz(N) | Ra(μm) |
| 1 | 2 | 50 | 0.04 | 0.5 | -32.0629 | -28.4715 | -7.53154 | -7.15870 |
| 2 | 2 | 50 | 0.04 | 0.5 | -30.9234 | -33.1907 | -11.6866 | -8.72325 |
| 3 | 2 | 50 | 0.08 | 1 | -40.4006 | -40.1293 | -6.84845 | -13.4420 |
| 4 | 2 | 50 | 0.08 | 1 | -35.9937 | -34.4477 | -11.7092 | -9.99374 |
| 5 | 2 | 50 | 0.12 | 1.5 | -41.0577 | -38.3122 | -13.9271 | -9.18785 |
| 6 | 2 | 50 | 0.12 | 1.5 | -43.4503 | -40.6314 | -8.62728 | -14.8702 |
| 7 | 2 | 100 | 0.04 | 0.5 | -34.0675 | -28.1987 | -4.65992 | -5.66602 |
| 8 | 2 | 100 | 0.04 | 0.5 | -32.7177 | -27.0745 | -4.81098 | -8.39911 |
| 9 | 2 | 100 | 0.08 | 1 | -40.3482 | -39.4958 | -0.748530 | -7.34712 |
| 10 | 4 | 100 | 0.08 | 1 | -19.7801 | -16.5345 | -5.52924 | -8.16480 |
| 11 | 4 | 100 | 0.12 | 1.5 | -26.2520 | -24.7960 | -3.86249 | 5.84860 |
| 12 | 4 | 100 | 0.12 | 1.5 | -31.0266 | -30.1571 | -4.19030 | -11.3875 |
| 13 | 4 | 150 | 0.04 | 1 | -17.8863 | -15.8478 | -6.06392 | -5.52924 |
| 14 | 4 | 150 | 0.04 | 1 | -23.2453 | -19.9826 | -5.93330 | -8.88090 |
| 15 | 4 | 150 | 0.08 | 1.5 | -29.4434 | -30.8838 | -4.34968 | -5.57507 |
| 16 | 4 | 150 | 0.08 | 1.5 | -26.8603 | -22.7976 | -6.60828 | -5.10545 |
| 17 | 4 | 150 | 0.12 | 0.5 | -32.2726 | -27.8820 | -4.34968 | -2.47703 |
| 18 | 4 | 150 | 0.12 | 0.5 | -33.7684 | -33.0643 | -1.93820 | -9.82723 |

**Table 3** S/N ratio of cutting forces and surface roughness

**Table 4** ANOVA FOR CUTTING FORCES Fx (N)

| Machining parameter | DoF | Sum of Square | Mean of square | F-ratio | P-ratio |
|---|---|---|---|---|---|
| Flute | 1 | 12397.3 | 12397.3 | 36.72 | 0.000 |
| Cutting speed | 2 | 1461.2 | 730.6 | 2.16 | 0.177 |
| Feed | 2 | 6853.0 | 3426.5 | 10.15 | 0.006 |
| DOC | 2 | 262.5 | 131.2 | 0.39 | 0.690 |
| Flute*Cutting speed | 2 | 3387.2 | 1693.6 | 5.02 | 0.039 |
| Error | 8 | 2700.9 | 337.6 | | |
| Total | 17 | 27062.1 | | | |

S = 18.3743 R-Sq = 90.02% R-Sq(adj) = 78.79%

**Table 5** ANOVA FOR CUTTING FORCES Fy ( N)

| Machining parameter | DoF | Sum of Square | Mean of square | F-ratio | P-ratio |
|---|---|---|---|---|---|
| Flute | 1 | 7494.2 | 7494.2 | 32.87 | 0.000 |
| Cutting speed | 2 | 485.7 | 242.9 | 1.07 | 0.389 |
| Feed speed | 2 | 7287.0 | 3643.5 | 15.98 | 0.002 |
| DOC | 2 | 55.3 | 27.6 | 0.12 | 0.887 |
| Flute*Cutting speed | 2 | 1469.0 | 734.5 | 3.22 | |
| Error | 8 | 1824.1 | 228.0 | | |
| Total | 17 | 18615.3 | | | |

S = 15.1002 R-Sq = 90.20% R-Sq(adj) = 78.18%

**Table 6** ANOVA FOR CUTTING FORCES Fz ( N)

| Machining parameter | DoF | Sum of Square | Mean of square | F-ratio | P-ratio |
|---|---|---|---|---|---|
| Flute | 1 | 4.2331 | 4.2331 | 20.77 | 0.002 |
| Cutting speed | 2 | 4.8039 | 2.4020 | 11.79 | 0.004 |
| Feed speed | 2 | 2.3671 | 1.1836 | 5.81 | 0.028 |
| DOC | 2 | 1.0180 | 0.5090 | 2.50 | 0.144 |
| Flute*Cutting speed | 2 | 3.4311 | 1.7156 | 8.42 | 0.011 |
| Error | 8 | 1.6304 | 0.2038 | | |
| | 17 | 17.4838 | | | |

S = 0.451448 R-Sq = 90.67% R-Sq(adj) = 80.18%

**Table 7** Analysis of Variance for surface roughness Ra

| Machining parameter | DoF | Sum of Square | Mean of square | F-ratio | P-ratio |
|---|---|---|---|---|---|
| Flute | 1 | 4.0993 | 4.0993 | 16.28 | 0.004 |
| Cutting speed | 2 | 2.1990 | 1.0990 | 4.37 | 0.052 |
| Feed speed | 2 | 7.2382 | 3.6191 | 14.37 | 0.002 |
| DOC | 2 | 6.0454 | 3.0227 | 12.00 | 0.004 |
| Flute*Cutting speed | 2 | 1.5852 | 0.7926 | 3.15 | 0.098 |
| Error | 8 | 2.0150 | 0.2519 | | |
| | 17 | 23.1822 | | | |

S = 0.501873 R-Sq = 91.31% R-Sq(adj) = 81.53%

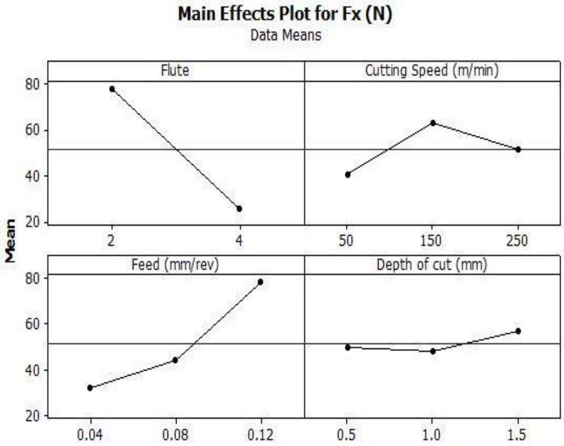


Fig. 5 Main effect plot of Fx

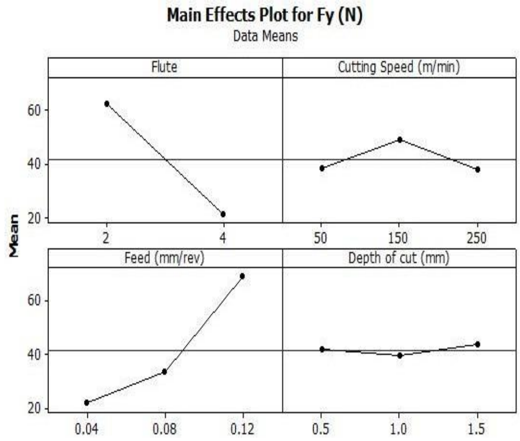


Fig. 6 Main effect plot of Fy

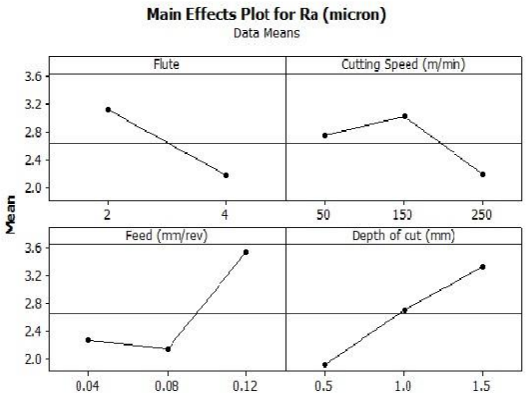


Fig. 7 Main effect plot of Fz

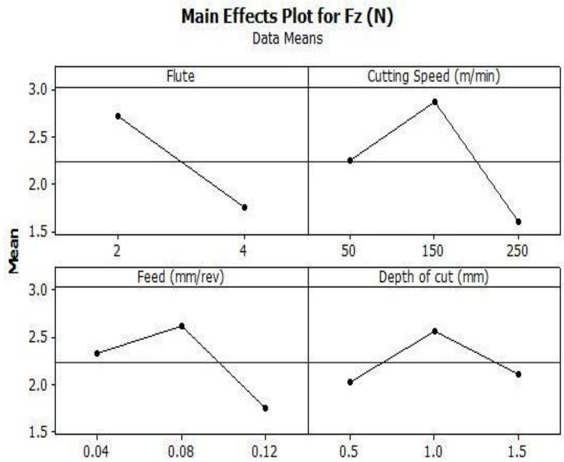


Fig. 8 Main effect plot of surface roughness

## 4. OPTIMIZED PARAMETER CONDITIONS

The optimization of the end milling on GFRP composite was investigated by varying different process parameters. Taguchi designs were used to determine a parameter combination that gives best and worst values of machinability indicators. Table 8 shows the optimum conditions.

| Response variable | | Optimized condition | | | |
|---|---|---|---|---|---|
| | | Flute | Cutting speed | Feed | Depth of cut |
| Cutting Force (Fx) | Better | 4 | 50 | 0.04 | 1 |
| | worst | 2 | 100 | 0.12 | 1.5 |
| Feed Force (Fy) | Better | 4 | 150 | 0.04 | 1 |
| | worst | 2 | 100 | 0.12 | 1.5 |
| Thrust Force (Fz) | Better | 4 | 150 | 0.12 | 0.5 |
| | worst | 2 | 100 | 0.08 | 1 |
| Surface Roughness (Ra) | Better | 4 | 150 | 0.08 | 0.5 |
| | worst | 2 | 100 | 0.12 | 1.5 |

The optimization table shows that various process parameters are needed to achieve both reduced cutting force and improved surface finish.

## CONCLUSIONS

The main purpose of the research was carry out to ascertain how process variables affected on GFRP composite through end milling operation. Following findings are derived from the experimental studies:

1. 1. The ANOVA shows that the cutting forces produced & surface finish during end milling on GFRP composite was statistically significantly influenced by the control parameters flute, feed, depth of cut & cutting speed. These variables was statistically significant at 95% confidence interval.
2. It was observed that at lower number of flute (2) and higher feed (1.0mm) the magnitude of cutting force is higher.
3. It was found from the analysis that the parameters number of flute and feed have statistically significant at 95% CI on the feed force.
4. It was observed that flute & cutting speed have statistically impact on the thrust forces at 95% confidence interval.
5. The ANOVA shows that the thrust force is at its minimum with more flutes, a greater cutting speed, feed and lower cut depth.

6. Relating the surface finish, flute, depth of cut & feed were most significant impacting control factor.

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