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An optimization of Machining Parameters On Cutting force and Surface Finish in Milling of Cs-GFRP

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Abstract:-Glass Fiber reinforced plastic (GFRP) composites are a feasible alternative to engineering materials and are being extensively used in variety of engineering applications. A study is conducted on machining of chopped strand glass fiber reinforced plastic (CS-GFRP) composites to investigate carried out for effect of cutting parameters (cutting speed, depth of cut and feed) In milling to achieve better surface finish and to reduce power requirement by reducing the cutting forces involved in machining. In this paper the effect of cutting conditions during milling machining on cutting force and surface roughness has been investigated. The experimental layout was designed based on the 2^k factorial techniques and analysis of variance (ANOVA) was performed to identify the effect of cutting parameters on surface finish and cutting forces are developed by using multiple regression analysis. The coefficients were calculated by using regression analysis and the model is constructed. The model is tested for its adequacy by using 95% confidence level. By using the mathematical model the main and interaction effects of various process parameters on end milling was studied.

***Keywords*'-GFRP, Universal milling machine, Surface Finish, Cutting Force, High Speed Steel Tool, Factorial Technique.**

I. INTRODUCTION

Composite materials milling is a rather complex task owing to its heterogeneity and some problems such as surface delamination appearing during the machining process, associated with the characteristics of the material and cutting parameters. Milling is the machining operation most frequently used in manufacturing of fibre reinforced plastics parts as a corrective operation to produce well-defined and high-quality surfaces that often require the removal of excess material to control tolerances [1]. AzlanMohdZain et al. observed best possible effect of the radial rake angle of the tool, speed and feed rate, cutting conditions in effecting the surface roughness. Surface roughness should be minimum for optimization technique. In the study, Grey Relational Analysis was done to find the optimal result of the cutting conditions and the study proved that the GRA is capable of estimating the optimal cutting conditions [2] .Davim et al. (2004) examined cutting speed and feed rate as input parameters and surface roughness and delamination as output parameters. K10 carbide tools were used for the milling process. Output parameters such as surface roughness and delamination were predicted using response surface method (RSM) [3] .Muthukrishnan et al. (2009) developed two modeling techniques used to predict the surface roughness namely ANOVA and ANN [4]. Pannerselvam et ai.(2012) studied the effect of machining parameters on end milling of GFRP composites in order to minimize surface delamination, machining forces , cutting torque and surface roughness. Sheikh-Ahmad et al [5]. Studied the comprehensive model for orthogonal milling of unidirectional composites at various fibre orientations. Kalla et al [6]. Studied the mechanistic modelling techniques for simulating the cutting of carbon fibre reinforced polymers (CFRPs) with a helical end mill. The aim of this work is to value cutting forces of carbon fibre reinforced plastics during the milling machining. This work aims to investigate the relationship among the cutting force and the surface finishing of machined laminate as a function of relevant cutting parameters, such as the cutting speed, axial depth of cut, and the feed rate. Factorial technique is a combination of Mathematical and statistical technique. It is useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize the response. For example, a person wishes to find levels of temperature (x1) and pressure (x2) that maximize the yield (Y) of a process. Equation (1) yields a function with the levels of temperature and pressure.

$$Y = f(x_1, x_2) + K$$

Where K represents the error or noise observed in the response Y. In most of the problems, the relationship between the response and the independent variable is unknown. The first step in factorial technique is to find suitable approximation for the true function of relationship between Y and the set of independent variables. Usually, a lower order polynomial in some region of the independent variables is employed. If the response is well modeled by a linear function of the independent variables then the approximating function is the first order model.

$$Y = K+AX_1+BX_2+CX_3$$

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If there is curvature in the system then a polynomial of higher degree must be used, such as the second order model.

$$Y=K+AX_1+BX_2+CX_3+ABX_1X_2+BCX_2X_3+CAX_3X_1+ABCX_1X_2X_3$$

II. PLAN OF INVESTIGATION

Step 1: Identification of the important process control variables.

Step 2: Finding the upper and lower limits of control variable.

Step 3: Developing the experimental design matrix.

Step 4: Conducting the experiments as per the design matrix.

Step 5: Recording the responses (surface finish & cutting forces).

Step 6: Development of mathematical models.

Step 7: Checking the adequacy of the developed models by using F –test.

III. MATHEMATICAL MODELLING

A) Identification of important process control variables

Identification of correct factors is very important to get a good and accurate model. Among them the parameters that influence the surface finish are speed, feed, depth of cut and nose radius.

Finding the limits of the process variables

Trial experiments are carried out to find out the value of cutting forces by changing one parameter and other are kept as constant.

- By varying the parameters, extreme limits are found out.
- For the convenience of recording and processing the experimental data observed.
- The upper and lower limits are coded as +1, -1 respectively or simply (+) and (-) for the case of recording.

Coded Value =(Natural value – Average value) / Variation in the value

Natural Value =Value under consideration

Average Value=(upper limit + lower limit)/2

Variation value = (upper limit – lower limit)

B) Development of Optimal Working Zones

The optimum working zone depends on the desired work piece. Experiments were conducted separately for each combination to find the operating working region. Finding of this region was necessary to fix up the limits of the process parameters. The upper and lower limits are denoted as +1 and –1 respectively. Trial runs were conducted by changing one of the factors and keeping the remaining at constant value. The maximum and minimum limits of all the factors were thus fixed.

C) Design of the Experiment

There are various techniques available from the statistical theory of experimental design which is well suited to Engineering investigations. One such important technique is a Factorial technique for studying the effects of parameters on response and this is the one which was selected for the experiment.The design of an experiment is the procedure of selecting the number of trails and conditions for running them, essential and sufficient for solving the problem that has been set with the required precision.

D) Conducting the Experiments as per the Design Matrix

The experiments are conducted according to the design matrix(shown in table.3.1, table.3.2). The number of passes required by a full 2^k factorial design increase geometrically as K is increased and the larger number of trials called for is primarily to provide estimates of the increasing number of higher order interactions, which are most likely do not exist. The measure of passes required to achieve the desired dimensional accuracy and surface finish is equal to 2^k.Where k is the number of input parameters. Hence unnecessary expenditure due to the loss of cutting time and operational cost may be saved using this relation. Factorial design constitutes the main parameters of major interests and is compounded (mixed up) with effects of higher order interactions and since these interaction effects are assumed to be small and negligible, the resulting estimates are essentially the main effects of primary interest.

E) Selection of Design and Mathematical Model

Fin of the machining parameters on the surface finish being the major part of investigation. It was considered best to design the experiments for the phase of study. This included the effect of maximum number of parameters could be used for all other phases.

Treatment Combination	K	A	B	C	AB	BC	CA	ABC
k	+	+	+	+	+	+	+	+
a	+	+	+	-	+	-	-	-
b	+	+	-	+	-	-	+	-
c	+	+	-	-	-	+	-	+
ab	+	-	+	+	-	+	-	-
bc	+	-	+	-	-	-	+	+
ca	+	-	-	+	+	-	-	+
abc	+	-	-	-	+	+	+	-

Table III.1: Design Matrix for Cutting Force

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Treatment Combination	K	A	B	C	AB	BC	CA	ABC
k	+	-	-	-	+	+	+	-
a	+	+	-	-	-	-	+	+
b	+	-	+	-	-	+	-	+
c	+	-	-	+	+	-	-	+
ab	+	+	+	-	+	-	-	-
bc	+	+	-	+	-	+	-	-
ca	+	-	+	+	-	-	+	-
abc	+	+	+	+	+	+	+	+

Table –III.2: Design Matrix for Surface Finish

F) Checking the Adequacies of the Models

All the above estimated coefficients were used to construct the models for the response parameter and these models were used to construct the models for the response parameter and these models were tested by applying analysis of variance (ANOVA) technique F-ratio was calculated and compared, with the standard values for 95% confidence level. If the calculated value is less than the F-table values the model is consider adequate.

G) Development of the Final Mathematical Model

The values predicted by this model were also checked by actually conducting experiments by keeping the value of the process parameter at some values other than those used for developing the models but within the zone and the results obtained were found satisfactory. Then these models were used for drawing graphs and analyzing the results.

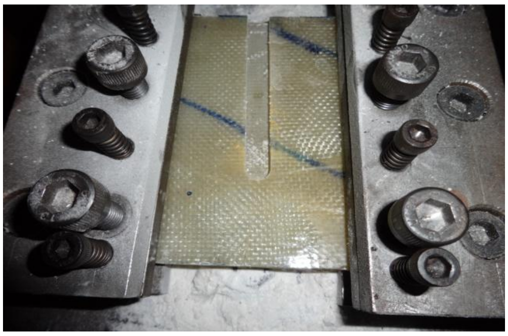
IV. EXPERIMENTAL WORK

Experimental work was conducted on a Universal milling machine. Glass Fiber reinforced plastic (GFRP) composites are chosen as work piece materials and High Speed Steel End milling Cutter is chosen as cutting tool material. Machining has been done as per the Design Matrix. In this current paper Speed, feed and Depth of Cut are chosen as the influencing parameters of Cutting Force and Surface Roughness and their minimum and maximum varying values are decided after conducting trail experiments Experimental work was conducted on a Universal milling machine. Glass Fiber reinforced plastic (GFRP) composites are chosen as work piece materials and High Speed Steel End milling Cutter is chosen as cutting tool material. Machining has been done as per the Design Matrix. In this current paper Speed, feed and Depth of Cut are chosen as the influencing parameters of Cutting Force and Surface Roughness and their minimum and maximum varying values are decided after conducting trail experiments.

Table –IV.I: Working limits of milling parameters

	Speed (rpm), A	Feed (mm/sec), B	depth of cut (mm), C
Maximum value	960 (+)	45 (+)	6 (+)
Minimum value	385 (-)	18 (-)	3 (-)

Fig IV.I: Conducting Experiments:



V. EXPERIMENTAL RESULTS

Table-V.I: Output response Values of Cutting Force.

Sno	Speed (rpm)	Feed (mm/sec)	Depth of Cut (mm)	Resultant Force (Kgf)
1	+	+	+	5.77
2	+	+	-	6.21
3	+	-	+	6.29
4	+	-	-	6.66
5	-	+	+	11.53
6	-	+	-	11.89
7	-	-	+	11.97
8	-	-	-	12.13

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Table -V.2: Experimental Values for Cutting Force.

Surface Roughness	Multi-Linear	Product of Multi-Linear
0.8	1.79	1.96
1	2.29	2.21
2.8	3.34	3.20
2.8	3.34	3.20
2.8	3.46	3.29
2.8	2.96	3.01
4.3	3.84	3.86
7.5	5.01	5.21

Table-V.3: Output response Values of Surface Roughness

Sno	Speed (rpm)	Feed (mm/sec)	Depth of Cut (mm)	Surface Roughness(um)
1	-	-	-	0.8
2	+	-	-	1
3	-	+	-	2.8
4	-	-	+	2.8
5	+	+	-	2.8
6	+	-	+	2.8
7	-	+	+	4.3
8	+	+	+	7.5

Sno	Speed (rpm)	Feed (mm/sec)	Depth of Cut (mm)	Surface Roughness(um)
1	-	-	-	0.8
2	+	-	-	1
3	-	+	-	2.8
4	-	-	+	2.8
5	+	+	-	2.8
6	+	-	+	2.8
7	-	+	+	4.3

Table-V.4: Experimental Values for Surface Roughness

VI. MODEL CALCULATION

Multi-Linear

$$F_K = K - AX_1 - BX_2 - CX_3$$

= [3.4-(-1.17*0.5)-(-1.55*0.5)-(-0.5*0.5)]=5.01

Product of Multi-Linear

$$F_K = [K - AX_1 - BX_2 - CX_3 + ABX_1X_2 + BCX_2X_3 + CAX_3X_1 - ABCX_1X_2X_3]$$

= (3.4-(-1.17*0.5)-(-1.55*0.5)-(-0.5*0.5)+ (0.22*0.25) + (0.45*0.25) + (0.075*0.25)-(-0.125*0.125))=5.21

VI. RESULTS AND DISCUSSION

VI.A. Variation of machining parameters on cutting forces

The effect of machining parameters (speed, feed and depth of cut) on cutting forces(is presented in following Fig VI.1,fig VI.2 and Fig VI.3). It is under stood that cutting forces increases with feed keeping other parameters constant, cutting forces increases with spindle speed keeping other parameters constant.

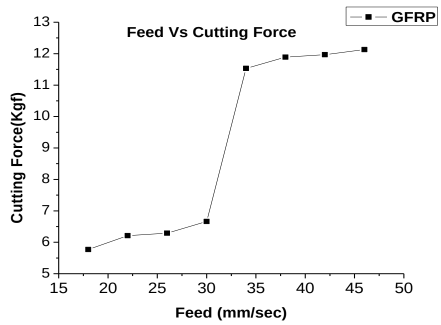

Fig-VI.1: Variation of Cutting Force with Speed

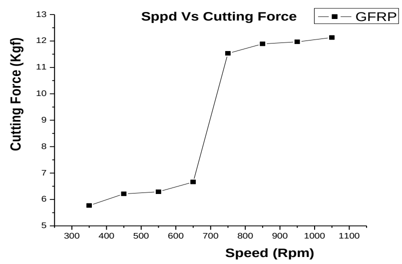

Fig-VI.2: Variation of Cutting Force with Feed

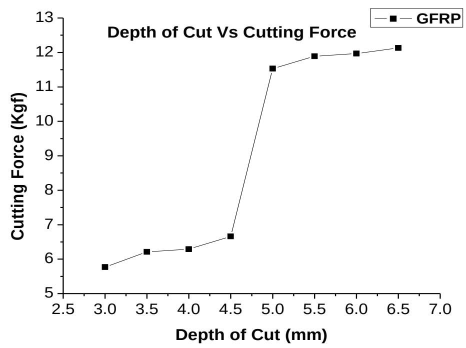

Fig-VI.3: Variation of Cutting Force with Depth of Cut.

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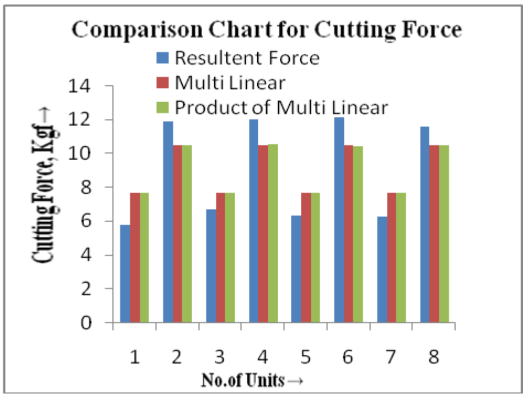

Fig-VI.4: Cutting Forces for Experimental Values of GFRP

VI.B. Variation of machining parameters on surface finish

The effect of machining parameters (speed, feed and depth of cut) on surface roughness(is presented in following Fig VI.5,fig VI.6 and Fig VI.7).It is understood that surface roughness increases with feed keeping other parameters constant, Surface roughness decreases with spindle speed keeping other parameters constant , surface roughness increases with spindle speed keeping other parameters constant

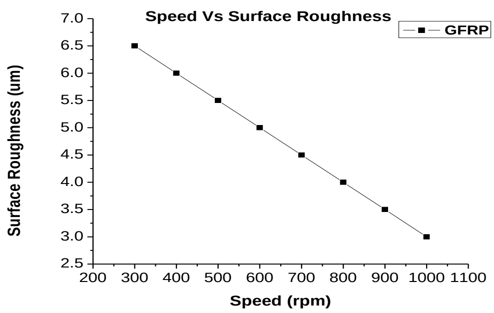

Fig-VI.6: Variation of Surface Roughness with Feed

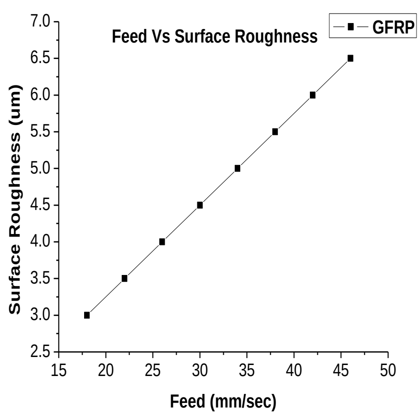

Fig-VI.5: Variation of Surface Roughness with Speed

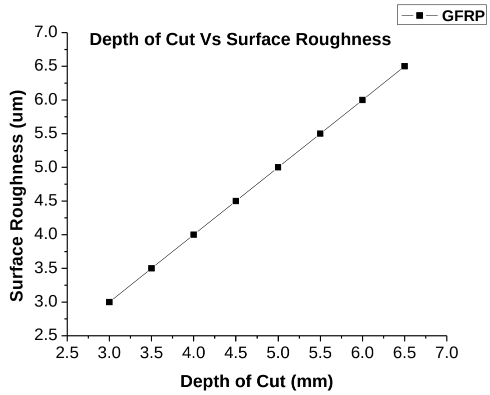

Fig-VI.7: Variation of Surface Roughness with Depth of Cut

- The experimental values and optimum values of surface finish and cutting forces are well within the limits for GFRP.
- As feed increases, the surface finish and cutting forces are increased by keeping speed and depth of cut as constant.
- As speed increases, the surface finish is decreased and cutting forces are increased by keeping feed and depth of cut as constant.
- As depth of cut increases, the surface finish and cutting forces are increased by keeping speed and feed as constant

VII. CONCLUSION

The developed model can be used to predict the surface finish and cutting forces in terms of machining parameters within the range of variables studied. Alternately, it also helps to choose the influential process parameters so that desired value of surface finish and cutting forces can be obtained. The effect of various process parameters like spindle speed, feed, depth of cut on surface finish and cutting forces were studied with their predicted values. In the future work the experiments can be carried out to determine the effect of parameters like spindle diameter, cutting fluid, cutting angle, Material removal rate etc., on the machined surfaces in milling operation.

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