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Abstract- Some invariable situations where component to be joined even though machining is not advisable for composites. But special situations here present work aimed at identifying better machining process parameters to arrive at defect free machined surfaces. In general laminated composite materials are machined at very high speed to generate a defect free machined surface. The precise measurement of cutting forces is very essential to know the influence of cutting forces of the work piece. In this connection precision machining is needed the present research work deals experimentations performed with two different mill tools and varieties of tool signatures are carefully analyzed with the mill tool dynamometer. 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. By using mathematical model with 90% confidence level the effects of various process parameters on end milling was studied. Finally, the ranges for best cutting process parameters and model equations to predict the cutting force components are proposed.

Keywords: universal milling machine, cutting force, specially designed carbide tipped end mill tool, solid carbide end mill tool, 2^k factorial techniques.

I. Introduction

Milling is most commonly used machining operation in fabrication of aerospace and automobile parts of fiber reinforced plastics, milling of composites rather difficult task owing due to heterogeneity of material and anisotropic behavior. Some of the problems which will raised after machining of composites even taking at most precautions for good surface finish and defect free operations. Generally any defects influenced in milling process due to characteristics of material, cutting forces and cutting process parameters. In this connection research and development have to be carried out through design of experiments to get a good results to minimize the power consumption and delamination. The users of GFRP are facing the difficulties when machining it, because basic knowledge and experience needed for conventional materials cannot be applaid for such new innovative materials whose ability to machine is different from that of conventional material (MONTGOMERY 1991). Thus it is desirable to investigate the behavior of FRPs during machining process. Bhatnagar et ai (1995) studied how the fiber orientation influence both the quality of machined surfaces and tool wear rate. The machinability of composites are influenced by the type of fiber inserted in the composites, and especially by mechanical properties. Palanikumar et al. (2006) studied the effect of cutting parameters on surface roughness on machining of GFRP composites by PCD tool by developing a second order model for predicting the surface roughness average. Palanikumar et al. (2008) developed a procedure to optimizing the factors choosing to attain minimum surface roughness by incorporating response table and graph, normal plot, interaction plots, and analysis of variance technique. 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 milling process.

II. Experimental Procedure and Schematic of Machining

a) Experimental Procedure

The experiments has been conducted to evaluate the influence of input parameters; speed, feed and depth of cut on cutting force for two different tools. The range of parameters investigated; speed of 961 rpm and 1950rpm, feed rate 25mm/min and 50mm/min and depth of cut 3mm and 5mm. The design of matrix for experimental runs is shown in table 2 and 5 for the two tools Experiments has been conducted as per the design matrix and the response, cutting force are measured with help of mill tool dynamometer.

b) Schematic of machining

The work piece is used for present work is Glass fiber reinforced polymer composite fabricated by Hand lay up method, 40 % uni-directional fiber and 60 %of polyester resin. The dimensions of work piece are 100mmx100mmx10mm. In this study, the experiments are carried out on a conventional milling machine incorporated by high speed spindle motor 10Hp to

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perform slots on work pieces by Specially designed two flute carbide tipped end mill tool and k- 10 Solid carbide end mill tool. All the process parameters are regulated in this experiment. Each experiment were conducted three times, use the average values from them, the cutting force readings are taken from all level of experiments by mill tool dynamometer from data analog output lap top set up.

III. Design of Experiment

A factorial technique is studying each factors from the experiments with effect of cutting process parameters on response which is selected from the experiments runs. The main factor can be estimated but may be confounded with two factor interactions. The number of passes required by partial 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. Where k is number of input parameters.

a) Exprimental Procedure as Per Taguchi Method (ANOVA) Factorial technique

Experimental work was conducted on Universal milling machine, uni-directional glass fiber reinforced composite choosen as work piece material, specially designed Carbide tipped end mill tool & solid carbide K-10 end mill tools are choosen as cutting tool materials. Machining has been done as per the design matrix. In present study influence of process parameters on cutting forces are taken apart from various parameters. Hence experimentation is performed by minimum and maximum values of speed, feed and depth of cut.

Table 1 : Working limits of milling parameters

Working limits of milling parameters	Speed (rpm) A	Feed (mm/min), B	Depth of cut (mm), c
Maximum value	1950 (+)	50 (+)	5 (+)
Minimum value	961 (-)	25 (-)	3 (-)

b) Estimated of Regression Coefficients

The regression coefficients are calculated by using fallowing formula based on method of least squares.

Bj = xjiyiN Where: J = 0, 1, 2…k, Yi=Average

N = Number of experimental trails, X = Number of columns of the designed matrix, Xi= value of a factor or interaction in coded form. A matrix designed to apply the above formula for the calculation of regression co-efficient of the model is given in tables. Because of the orthogonal property of the design, the estimated coefficients are un correlate with one another. Since the method of least squares has been used to estimate the property of minimum variance. All the regression coefficients of the model are expressed by the above expression. The response parameters are estimated are also by taking standard Fishers ratio table. In the present case the tabulated value of F-ratio was found out as follows: $F_{ratio}=2x(S^2_{ad}/S^2_{y})$ Where, S^2_{ad}= Variance of adequacy or residual variance S^2y=Variance of optimization parameter of variance of reproducibility. The variance of adequacy was calculated by $S^2_{ad}=2(y_{avg} - y_{pre)})^2$ /DOF Where y_{avg}=Value of response predicted. DOF=Degree of freedom and is equal to (n-(K+1), N = No of experimental trials, K =No. of independent variables, $S^2_y=2\ (y_1-y_{avg})\ ^2$/DOF Y_{avg}=average of response observed, Y_1=other of the values of response parameter, DOF=Degree of freedom is equal to the number of experimental runs. The values are 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. The comparison of two different tools are also predicted and then these models were used, represented by using the graphs and analyzing the results as shown from comparative table also.

IV. Results and Discussion

Table 1 : Calculation of experimental values for special carbide end mill tool

EXP.	N	f	d	F	F^2
1	+	+	+	1.91	3.6481
2	+	+	+	1.91	3.6481
3	+	+	-	1.2	1.44
4	+	-	-	0.5	0.25
5	+	-	-	1.82	3.3124
6	+	-	+	1.62	2.6244
7	+	-	+	0.4	0.16
8	+	+	-	2.1	4.41

Table 2 : Design matrix for cutting force of GFRP by special carbide end mill tool

EXP.	K	A	B	C	AB	BC	AC	ABC
1	+	+	+	+	+	+	+	+
2	+	+	+	-	+	-	-	-
3	+	+	-	-	-	+	-	+
4	+	-	-	-	+	+	+	-
5	+	-	-	+	+	-	-	+
6	+	-	+	+	-	+	-	-
7	+	-	+	-	-	-	+	+
8	+	+	-	+	-	-	+	-

Table 3 : Fishers values for cutting force of GFRP by special carbide end mill tool

K	RC	SS	DOF	FR
A	0.3475	0.4683	1	0.27
B	0.03	0.0036	1	0.0021
C	0.43	0.7396	1	0.435
AB	0.1025	0.042	1	0.024
BC	-0.125	0.0625	1	0.0367
AC	-0.08	0.0256	1	0.015
ABC	-0.1	0.04	1	0.23
SSR	1.4	7		
SST	3.07	15		
SSE	1.7	8		

Table 4 : Calculation of experimental values for solid carbide K-10 end mill tool

EXP NO	N	f	d	F	F^2
1	+	+	+	2.816	7.92
2	+	+	+	2.5	625
3	+	+	-	2.5	6.25
4	+	-	-	4.7	22.09
5	+	-	-	3	9
6	+	-	+	2.2	4.84
7	+	-	+	0.7	0.49
8	+	+	-	3.7	13.69

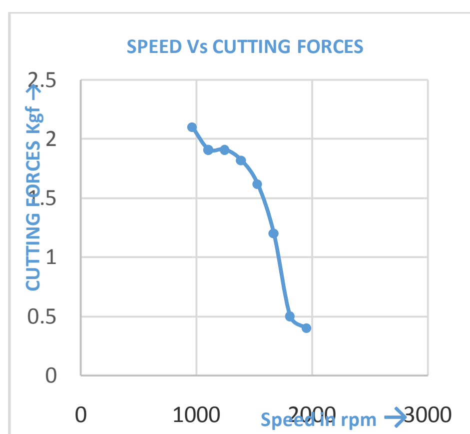
Table 5 : Design matrix for cutting force of GFRP by solid k 10 carbide tool

EXP.	K	A	B	C	AB	BC	AC	ABC
1	+	+	+	+	+	+	+	+
2	+	+	+	-	+	-	-	-
3	+	+	-	-	-	+	-	+
4	+	-	-	-	+	+	+	-
5	+	-	-	+	+	-	-	+
6	+	-	+	+	-	+	-	-
7	+	-	+	-	-	-	+	+
8	+	+	-	+	-	-	+	-

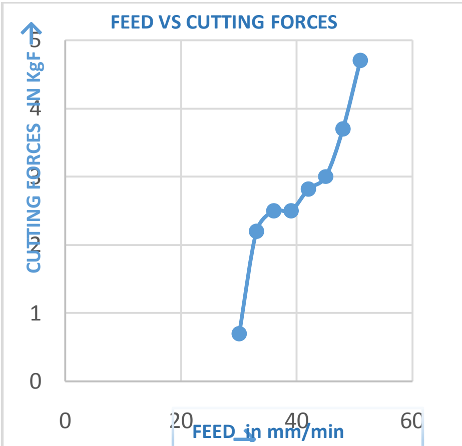
Table 6 : Fishers values for cutting force of GFRP by solid carbide K-10 end mill tool

Where, N=Speed, f=Feed, d=Depth of cut, RC=Regression coefficients, FR=Fishers ratio

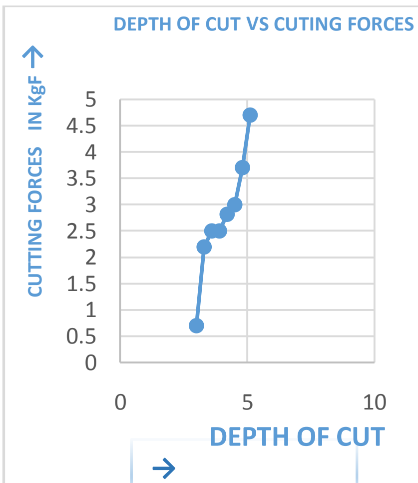
K	RC	SS	DOF	FR
A	0.1145	0.052	1	0.009
B	-0.71	2.01	1	0.36
C	0.164	0.108	1	0.02
AB	0.49	0.108	1	0.12
BC	0.29	0.36	1	0.064
AC	0.215	0.184	1	0.033
ABC	-0.51	1.04	1	0.184
SSR	3.71	7		
SST	9.4	15		
SSE	5.65	8		



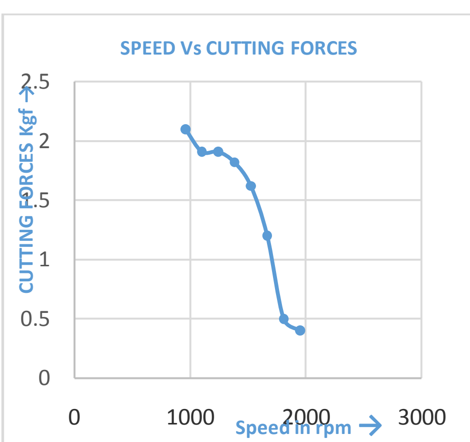
Graph 1 : Showing Variation of Cutting Force with Speed By special Carbide tipped end mill tool



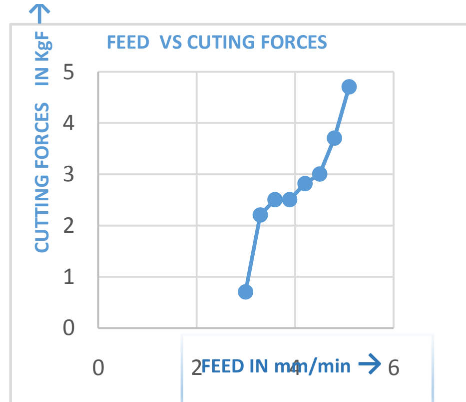
Graph 2 : Showing Variation of Cutting Force with Feed By special Carbide tipped end mill tool



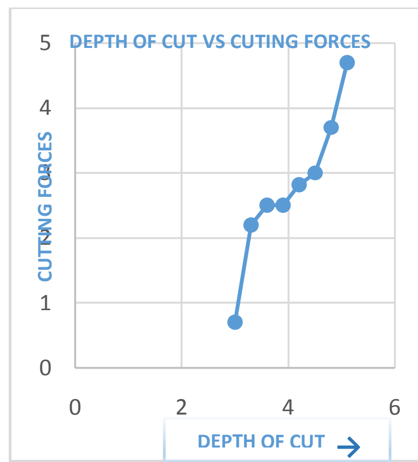
Graph 3 : Showing Variation of Cutting Force with Depth of cut By special Carbide tipped end mill tool



Graph 4 : Showing Variation of Cutting Force with Speed By special Carbide K-10 end mill tool



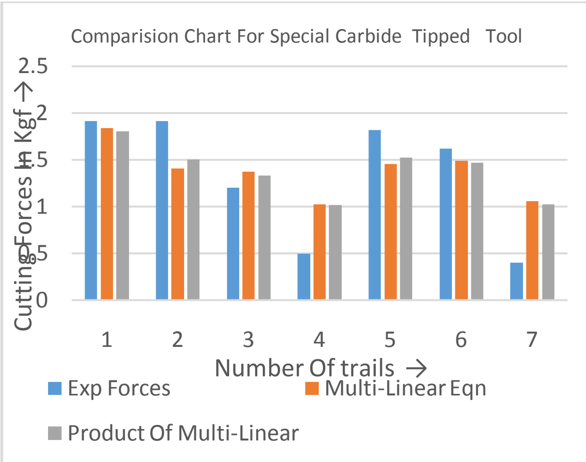
Graph 5 : Showing Variation of Cutting Force with Feed By Solid Carbide K-10 end mill tool



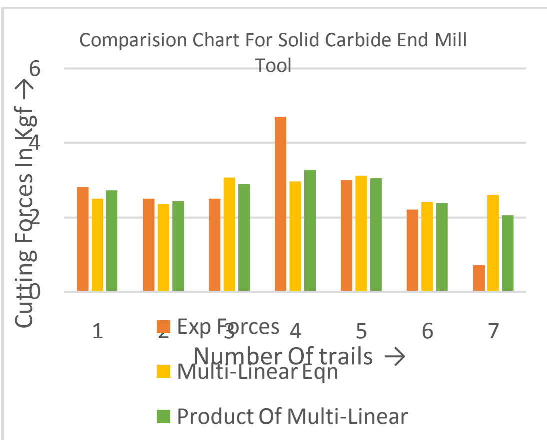
Graph 6 : Showing Variation of Cutting Force with Depth of cut By Solid Carbide K-10 end mill tool

a) Variation of Process parameters with cutting Force

The effect of machining parameters (speed, feed and depth of cut) on cutting forces is presented in following Fig. It is understood that Cutting forces increases with feed keeping other parameters constant,Cutting forces decreases with spindle speed keeping other parameters constant, Cutting forces increases with spindle speed keeping other parameters constant.



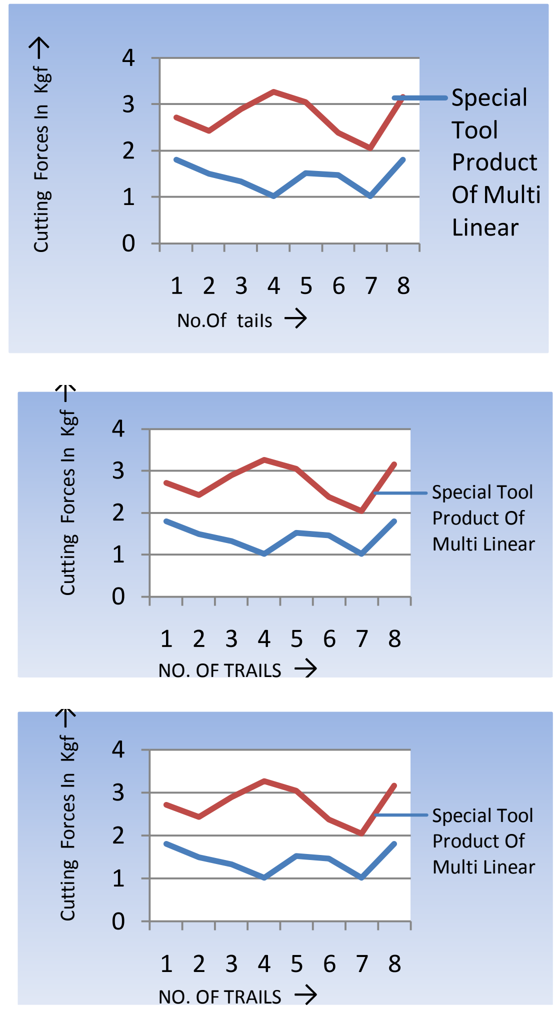
Graph 7 : Comparison of Cutting Forces for Experimental Values Of UD-GFRP By Solid K-10 Carbide mill tool



Graph 8 : Comparison of Cutting Forces for Experimental Values of special Carbide end mill tool

Table 8 : Comparison table for Cutting Force Values of Two different tools

With Special Carbide End Mill Tool			With Carbide k-10 End Mill Tool		
Resultant Force	Multi-Linear	Product of Multi-Linear	Resultant Force	Multi-Linear	Product of Multi-Linear
1.91	1.836	1.80375	2.816	2.5	2.72
1.91	1.406	1.5	2.5	2.36	2.43
1.2	1.376	1.33	2.5	3.07	2.9
0.5	1.028	1.021	4.7	2.96	3.27
1.82	1.458	1.52	3	3.125	3.05
1.62	1.488	1.47	2.2	2.42	2.38
0.4	1.058	1.026	0.7	2.6	2.05
2.1	1.806	1.8	3.7	3.07	3.16



Graphs 9, 10, 11 : Variation of cutting forces with special and solid end mill tools from above comparison table

From the above graphs involving variation of forces in case of using special carbide tipped end mill tool and solid carbide k-10 end mill tool, it was found that the cutting forces involved in machining of uni-directional glass polyester composites are less with specially designed carbide tipped tool when compared to solid end mill tool. So there is possibility to obtain reduction of power consumption, tool wear rate and can get good surface finish with specially designed carbide tipped end mill tool.

V. Conclusion

- Factorial Method is convenient to predict the main effects and the interaction effects of different influential combination of end milling process parameters within the range of investigations on cutting forces involved during machining.
- By comparing the cutting forces obtained by use of tools in machining of the GFRP, it was found by application of DOE principles (ANOVA) that the

special carbide tipped tool was found to exert low cutting forces than the regular carbide K-10 end mill tool.

- Hence we can change the nomenclature of special tool, the cutting forces are to be reduced and here proved from correlation of DOE and actual experimental work.
- Factorial Method is easy and accurate method for developing mathematical models for predicting the cutting forces within the working region of the process variables.
- So these kind of specially designed carbide tipped end mill tools are best suitable for machining of GFRP composite laminates in most of industrial applications.

VI. Scope of the Work

In the present investigation it was found that the various process input parameters which effects the cutting forces were studied with their predicted values. In the future work the experiments can be carried out to determining the effect of some other process parameters like spindle diameter, Surface roughness, material removal rate etc., on the machined surfaces in milling operation. Also on further change in nomenclature of special tool the forces can be reduced along with power consumption and tool wear rate, so also tool life increases.

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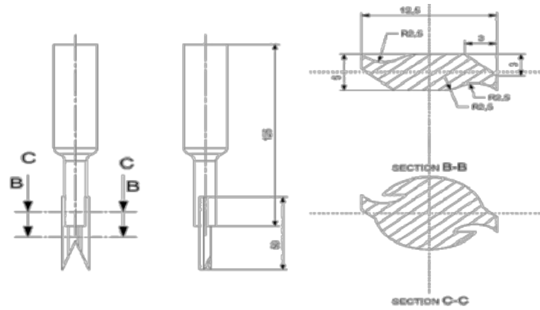

Special designed Carbide end mill Tool Details

- Rake Angle : 35 degrees
- Clearance Angle : 8 -10 degrees
- Helix Angle : 30 degrees

End mill tool details

- Rake Angle : 45degrees
- Clearance Angle : 10-12 degrees
- Helix Angle : 35degrees