ISSN : 2454-9150 Vol-04, Issue-01, Apr 2018

Effect of Machining Parameter in GFRP Composite During End Milling Using WC-CO Tool

[1]L. Martin, [2]V.S.K Venkatachalapathy, [3]A.Selvaraju

[1]Research Scholar, Department of Mechanical Engineering, Pondicherry Engineering College, Pondicherry, India. martinsudhan@smvec.ac.in

[2]Professor, Department of Mechanical Engineering, Sri Manakula Vinayagar Engineering College, Pondicherry, India

[3]Professor, Department of Mechanical Engineering, Pondicherry Engineering College, Pondicherry, India.

***Abstract*— This project deals glass fibre reinforced polymer (GFRP) composite. In this work, the cutting parameters were set as three levels of spindle speed (1000, 1500, 2000 rpm), three levels of feed rate (150,200,250 mm/min), and three levels of depth of cut (0.75, 1, 1.25 mm). An experimental plan, based on L27 orthogonal array techniques and on the analysis of variance (ANOVA), was established considering milling with prefixed cutting parameters for GFRP composite plates using solid carbide end mills. The Taguchi method is used to formulate the experimental layout, to analyse the effect of each parameter on the machining characteristics, and to predict the optimal choice for each end milling parameter such as Speed, Feed, and Depth of cut. It is found that these parameters have a significant influence on machining characteristic such as material removal rate, surface roughness and delamination.**

The analysis using Taguchi method reveals that from the graph delamination factor value decrease with decreasing the feed rate and depth of cut and increasing with the spindle speed, whereas the surface roughness value decrease with decreasing the feed rate and depth of cut and decrease with increasing the spindle speed. The feed and depth of cut have to be maintained at lower level and speed in medium level yields better material removal rate. Depth of cut and feed rate is the most significant parameter and spindle speed is the least significant parameter for milling of GFRP composite with the objective of minimizing surface roughness, and delamination factor.

Keywords-component; GFRP, L27 orthogonal array, Tensile strength, Hardness, Surface Roughness, Delamination Factor

I. INTRODUCTION

In recent years, glass fiber-reinforced polymer (GFRP) are being widely used in variety of engineering applications in many different fields such as aerospace, automotive and aircraft industries due to their light weight, high modulus, high specific strength and high fracture toughness. Milling composite materials is a difficult task due to its heterogeneity and the number of problems, such as surface delamination, surface roughness, and fiber pullout associated with the characteristics of the material and the cutting parameters that appear during the machining process. .

In order to reduce these problems we present this study with the objective of evaluating the cutting parameters (depth of cut , spindle speed and feed rate) and the influence of the fibers under delamination factor (Fd) and surface roughness (Ra) and material removal rate .Proper selection of manufacturing conditions is one of the most important aspects in the milling Machining process, as these conditions determine important characteristics such as Material Removal Rate , delamination and Surface Roughness.

II. LITERATURE REVIEW

In an automated manufacturing environment it is possible to increase machine utilization and decrease production cost [1]. Optimal cutting parameters for work piece surface temperature and surface roughness were obtained employing Taguchi techniques [2]. To optimize surface quality in a CNC face milling an orthogonal array and ANOVA were carried out to identify the best surface roughness and signal-to-noise ratio [3]. Ultrasonic machining technique is ascribing to higher cutting temperature which will result into local softening of work material and more damaged on the machined surface [4].

Non-traditional machining processes such as laser cutting, water-jet cutting, ultrasonic cutting, electro discharge machining have been developed for an application on FRP for machining. Due to inhomogeneous and anisotropic structure of FRP milling causes problem which do not occur in other materials [5]. Among the defects caused by

 DOI : 10.18231/2454-9150.2018.0108 © 2018, IJREAM All Rights Reserved.

ISSN : 2454-9150 Vol-04, Issue-01, Apr 2018

milling, delamination appears to be the most critical, which can result in a lowering of bearing strength and can often become a limiting factor in the use of FRP for structural application[6]. GFRP components are largely made near net shape and any subsequent milling is limited mainly to de-burring and trimming as well as to achieve contour shape accuracy [7]. Increasing in cutting speed improves machinability, surface finish and maximum metal removal it is preferable to use high cutting speed associated with depth of cut [8]. Increase in spindle speed and the depth of cut deteriorates the surface finish [9].

III. Experimental Procedure

Glass fibre reinforced plastics (GFRP) composite plates made by Hand lay-up method are used for these experiments. The GFRP is made of glass FRP Woven cloth with epoxy resin with the ratio of 50: 50. First one layer of resin is applied and then one layer of GFRP woven cloth laid on the resin layer and hand roller was rolled on it with pressure. The same procedure was repeated to achieve 8mm thickness. Finally job was kept in autoclave for curing for 48 hours. The work piece is ready for milling operation. GFRP plates are of 110 mm x 90 mm x 8 mm thick with 15 lay-up with desired fibre orientation (0° / 90°) are used for the milling operations. The ultimate tensile strength and density of the work piece are 1770 MPa and 1.8 gm/cm³ respectively. A commercially available solid carbide tool is used for machining.

A. *Materials used*

a. Thinner
b. Wax
c. Molding Board
d. Brushes
e. Roller
f. Hack Saw blade
g. Mechanical stirrer
h. Epoxy Resin(LY556)
i. Hardener(HY951)
j. Instant Cure Adhesive
k. Rubber sheet
l. Woven Roving Mat

B. *Properties of Woven Roving Mat*

- High strength and modulus
- Temperature stability
- Flex performance
- Dimensional resistance
- Chemical resistance

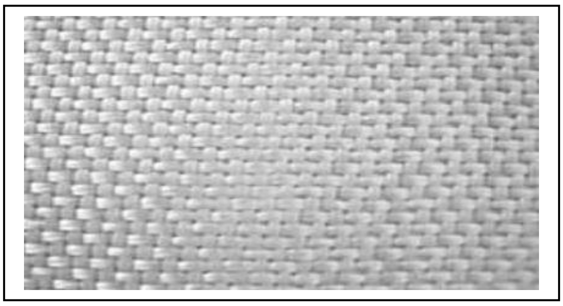

Figure 1. Woven Roving Mat

C. *Formulation of Composite laminates*

- 15 layer of mat will be used to make 1 laminate
- Weight of glass fiber = 950±5 g
- Taking 1:1 ratio of matrix and fiber.
- The amount of resin = 950±5 g.
- 10 % of hardener = 95±5 g.
- Overall dimension of plate= 400*300*8 mm
- Size of plates = 100*90*8 mm.

D. *Selection of process parameters*

The selection of right combination of process parameters and setting the range of the process parameters is very important step in any unconventional machining process. The small changes in process parameters lead to more variation in surface roughness and accuracy of the machined components. In the present work there are two process parameters are considered namely (i) fixed parameters and (ii) controlled parameters. The fixed parameter will not change throughout the investigation. The table 1 shows the fixed parameters considered in the experimentation.

TABLE I. Fixed Parameters For End Milling

Fixed Parameters For End Milling		
SL NO	**Fixed Parameters**	**Description**
1	Milling cutter size	10.0 mm diameter
2	Shape of the work piece	Rectangular
3	Size of the work piece	110 × 90×8 mm thick
4	Location of work piece on working table	Centre of the table
5	Input voltage	415 V

The change of values of parameters considered during each experiment is known as controlled parameters. The focus of investigation is mainly on these parameters to achieve the desired objective. The table II shows the controlled parameters. The levels of the parameters selected as per the CNC machine used in the work.

TABLE II. Controlled Parameters For End Milling

Controlled Parameters For End Milling						
SL NO	Control Parameters	Symbol	Unit	Levels-I	Levels-II	Level-III
1	Speed	N	RPM	1000	1500	2000

 DOI : 10.18231/2454-9150.2018.0108 © 2018, IJREAM All Rights Reserved.

ISSN : 2454-9150 Vol-04, Issue-01, Apr 2018

Controlled Parameters For End Milling						
SL NO	Control Parameters	Symbol	Unit	Levels-I	Levels-II	Level-III
2	Feed	f	mm/min	150	200	250
3	Depth of cut	d	mm	0.75	1.0	1.25

E. *Taguchi design of experiments*

Based on the factors considered and degrees of freedom of all factors appropriate Orthogonal Array may be selected. In the present investigation three controlled process parameters at three levels are considered as shown in the table.

TABLE III. TAGUCHI DESIGN L27 ORTHOGONAL ARRAY

Taguchi Design L27 Orthogonal Array			
SL NO	A	B	C
1	1	1	1
2	1	1	1
3	1	1	1
4	1	2	2
5	1	2	2
6	1	2	2
7	1	3	3
8	1	3	3
9	1	3	3
10	2	1	2
11	2	1	2
12	2	1	2
13	2	2	3
14	2	2	3
15	2	2	3
16	2	3	1
17	2	3	1
18	2	3	1
19	3	1	3
20	3	1	3
21	3	1	3
22	3	2	1
23	3	2	1
24	3	2	1
25	3	3	2
26	3	3	2
27	3	3	2

F. *Selection of milling cutter*

Carbide -This tool material combines increased stiffness with the ability to operate at higher SFPM. Carbide tools are best suited for shops operating newer milling machines or machines with minimal spindle wear. Rigidity is critical when using carbide tools. Carbide end mills may require a premium price over the cobalt end mills, but they can also be run at speeds 2 1/2 faster than HSS end mills. The cutting tool used is a commercially available solid carbide tool.

The specifications of the cutting tool are as follows:

- Cutter Diameter = 10 mm.
- FULL Length = 72 mm.
- Foot length= 32mm.
- Body length=40 mm.
- Helix Angle =30°.
- No. of flutes = 04.

G. *Performing milling operation*

Figure 2. CNC vertical machining center

Milling can be done with a wide range of machine tools. The original class of machine tools for milling was the milling machine (often called a mill). After the advent of computer numerical control (CNC), milling machines evolved into machining centers (milling machines with automatic tool changers, tool magazines or carousels, CNC control, coolant systems, and enclosures), generally classified as vertical machining centers (VMCs) and horizontal machining centers (HMCs).

Figure 3. Machining of GFRP by CNC vertical machining center with carbide End Mill

The milling process removes material by performing many separate, small cuts. This is accomplished by using a cutter with many teeth, spinning the cutter at high speed, or advancing the material through the cutter slowly; most

 DOI : 10.18231/2454-9150.2018.0108 © 2018, IJREAM All Rights Reserved.

ISSN : 2454-9150 Vol-04, Issue-01, Apr 2018

often it is some combination of these three approaches. The speeds and feeds used are varied to suit a combination of variables. The speed at which the piece advances through the cutter is called feed rate, or just feed; it is most often measured in length of material per full revolution of the cutter.

H. Measure the surface roughness with the help of a portable Surface roughness tester TR100

The demand for high quality and fully automated production focuses attention on the surface condition of the product, especially the roughness of the machined surface, because of its effect on product appearance, function, and reliability. For these reasons it is important to maintain consistent tolerances and surface finish. Also, the quality of the machined surface is useful in diagnosing the stability of the machining process, where a deteriorating surface finish may indicate work piece material non-homogeneity, progressive tool wear, cutting tool chatter, etc.

The surface roughness (Ra) was evaluated using portable Surface roughness tester TR100. For each test, five measurements were made over milling surfaces.

Figure 4. Measurement of surface roughness using from Surface roughness tester TR100

I. Measure the delamination with the help of a tool maker's microscope.

Delamination is a mode of failure for composite materials .Fiber pull-out (another form of failure mechanism) and delamination can occur, in part, due to weak adhesive bonding between the fibers and the polymer matrix. Delamination is defined as "the separation of the opposite or adjacent layers of material in a laminate." Delamination can occur at any time in the life of a laminate for various reasons and has various effects. It can affect the tensile strength performance depending on the region of Delamination.

This factor is defined as the quotient between the maximum width of damage (Wmax), and the width of cut (W). The value of delamination factor (Fd) can be obtained by the following equation:

$$F_d = W_{max} / W$$

Wmax being the maximum width of damage in mm and W be the width of cut in mm.

Figure 5. Measurement of of delamination damage using Tool makers Microscope

J. Calculate the material removal rate (MRR)

The material removal rate, MRR, can be defined as the volume of material removed divided by the machining time. Another way to define MRR is to imagine an "instantaneous" material removal rate as the rate at which the cross-section area of material being removed moves through the work piece. The material removal rate (MRR) using the following formula

MRR = (Initial weight – Final Weight) / (Density of work piece x Machining Time)

IV. RESULTS AND DISCUSSION

The experiments are planned using Taguchi's orthogonal array in the design of experiments (DOE), which helps in reducing the number of experiments. The experiments were conducted according to orthogonal array.

The three cutting parameters selected for the present investigation is depth of cut (d) in mm, Spindle speed (N) in rpm, Feed rate (f) in mm/min. Taguchi's orthogonal array of L27 is considered for this work. This needs 27 runs and has 26 degrees of freedom. The machining parameter used and their levels are shown in Table 5. The experimental test conditions and observed data based on L27 orthogonal array are shown in Table II.

The results of the milling tests allowed the evaluation of the GFRP composite material manufacture by hand-layup, using solid carbide end mills. The Machinability was evaluated by surface roughness (Ra), delamination factor (Fd) and material removal rate.

TABLE IV. EXPERIMENTAL TEST CONDITIONS AND OBSERVED DATA

Experimental test conditions and observed data						
SL NO	*N(rpm)*	*f(mm/min)*	*d(mm)*	*Ra (μm)*	*Fd*	*MRR (cm^3/min)*
1	1000	150	0.75	1.052	1.009	0.8697
2	1000	150	0.75	1.112	1.015	0.8765

 DOI : 10.18231/2454-9150.2018.0108 © 2018, IJREAM All Rights Reserved.

ISSN : 2454-9150 Vol-04, Issue-01, Apr 2018

Experimental test conditions and observed data						
SL NO	*N(rpm)*	*f(mm/min)*	*d(mm)*	*Ra (µm)*	*Fd*	*MRR (cm³/min)*
3	1000	150	0.75	1.152	1.019	0.9778
4	1000	200	1	1.191	1.025	1.825
5	1000	200	1	1.197	1.012	1.979
6	1000	200	1	1.205	1.021	2.048
7	1000	250	1.25	1.217	1.032	2.52
8	1000	250	1.25	1.224	1.024	2.567
9	1000	250	1.25	1.219	1.017	2.479
10	1500	150	1	1.139	1.011	1.906
11	1500	150	1	1.142	1.021	1.906
12	1500	150	1	1.148	1.034	1.906
13	1500	200	1.25	1.421	1.04	1.881
14	1500	200	1.25	1.456	1.057	1.384
15	1500	200	1.25	1.532	1.031	1.1036
16	1500	250	0.75	1.613	1.067	3.031
17	1500	250	0.75	1.765	1.058	2.142
18	1500	250	0.75	1.793	1.061	2.1727
19	2000	150	1.25	0.856	1.038	0.9897
20	2000	150	1.25	0.955	1.047	1.221
21	2000	150	1.25	1.056	1.075	0.762
22	2000	200	0.75	1.115	1.059	1.792
23	2000	200	0.75	1.185	1.079	2.253
24	2000	200	0.75	1.254	1.032	1.52
25	2000	250	1	1.297	0.092	0.9357
26	2000	250	1	1.312	1.047	2.464
27	2000	250	1	1.367	1.057	2.4585

A. Influence of the cutting parameters based on S/N Ratio

Table IV shows the results of the surface roughness (Ra), material removal rate (MRR) and delamination factor (Fd) as a function of the cutting parameters for the GFRP composites. Table V, Table VI, Table VII illustrates the results of Taguchi analysis (S/N ratio) for surface roughness, material removal rate (MRR) and delamination factor (Fd) using the approach of smaller is better.

From Table V it is observed that the feed rate is the most significant parameter followed by spindle speed and depth of cut for the surface roughness of GFRP composites. From Table VI it is understood that the feed rate is the most significant parameter followed by depth of cut and spindle speed for delamination factor of GFRP composites. From Table VII it is understood that the feed rate is the most significant parameter followed by depth of cut and spindle speed for material removal rate of GFRP composites. From the above analysis, the feed rate is seen to make the largest contribution to the overall performance.

TABLE V. SIGNAL TO NOISE RATIOS FOR THE SURFACE ROUGHNESS OF GFRP COMPOSITES

Signal to noise ratios for the surface roughness of GFRP composites			
Levels	N(rpm)	f(mm/min)	d(mm)
1	-1.3900	-0.5582	-2.3653
2	-3.0826	-2.1325	-1.7255
3	-1.1894	-2.9714	-1.5712
Delta	1.8932	2.4132	0.7941
Rank	2	1	3

TABLE VI. SIGNAL TO NOISE RATIOS FOR THE DELAMINATION OF GFRP COMPOSITES

Signal to noise ratios for the delamination of GFRP composites			
Levels	N(rpm)	f(mm/min)	d(mm)
1	-0.1664	-0.2551	-0.3755
2	-0.3584	-0.3367	0.3160
3	0.1238	0.1908	-0.3415
Delta	0.4822	0.5275	0.6915
Rank	3	1	2

TABLE VII. SIGNAL TO NOISE RATIOS FOR MATERIAL REMOVAL RATE OF GFRP COMPOSITES

Signal to noise ratios for the material removal rate of GFRP composites			
Levels	N(rpm)	f(mm/min)	d(mm)
1	-4.341	-1.617	-4.185
2	-5.658	-4.922	-5.927
3	-3.973	-7.434	-3.860
Delta	1.685	5.817	2.067
Rank	3	1	2

B. Effect of process parameters on surface roughness, material removal rate and delamination factor based on response table

The influence of different machining parameters on milling of GFRP composites can be studied by using response graphs and response tables. The influence of cutting parameters on surface roughness, delamination factor and material removal rate are shown in Fig. 6, 7, 8 and their main effects are shown in Table VIII, IX, X

TABLE VIII. RESPONSE TABLE FOR SURFACE ROUGHNESS

Response table for surface roughness			
Levels	N(rpm)	f(mm/min)	d(mm)
1	1.174	1.068	1.338
2	1.445	1.284	1.222
3	1.155	1.423	1.215
Optimum levels	N3	f1	d3

 DOI : 10.18231/2454-9150.2018.0108 © 2018, IJREAM All Rights Reserved.

ISSN : 2454-9150 Vol-04, Issue-01, Apr 2018

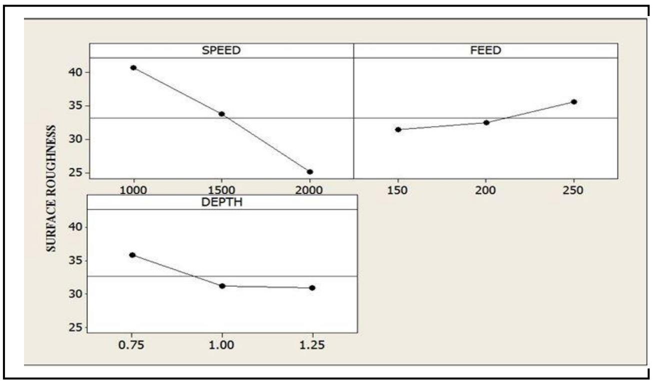

Figure 6. Illustration of factor effects on surface roughness

From the figure 6, it is realized that surface roughness increases with increasing the feed rate, whereas the surface roughness decreases with increasing the spindle speed and depth of cut. Based on the main effect plot and response table for surface roughness, the optimal level of each parameter is set at N3 f1 d3 for the surface roughness.

TABLE IX. RESPONSE TABLE FOR DELAMINATION

Response table for delamination			
Levels	N(rpm)	f(mm/min)	d(mm)
1	1.0193	1.0299	1.0443
2	1.0422	1.0396	0.9244
3	0.9473	0.9394	1.0401
Optimum levels	N3	f3	d2

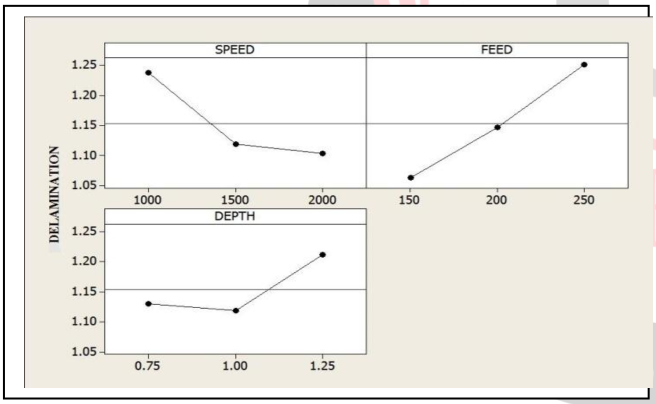

Figure 7. Illustration of factor effects on delamination factor

From the figure 7, it is observed that delamination factor value increases with increasing the feed rate and depth of cut, whereas the delamination factor value decreases with increasing of the spindle speed. Based on the main effect plot and response table for delamination factor, the optimal level of each parameter is set at N3 f3 d2 for delamination.

TABLE X. RESPONSE TABLE FOR MATERIAL REMOVAL RATE

Response table for material removal rate			
Levels	N(rpm)	f(mm/min)	d(mm)
1	1.794	1.268	1.737
2	1.937	1.754	1.936
3	1.600	2.308	1.656
Optimum levels	N2	f3	d2

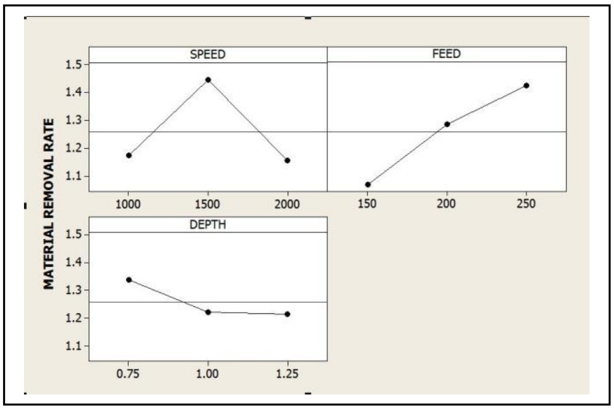

Figure 8. Illustration of factor effects on material removal rate

From the figure 8, it is observed that the depth of cut have to be maintained at lower level and speed in medium level yields better material removal rate. Based on the main effect plot and response table for machining force, the optimal level of each parameter is set at N2 f3 d2 for material removal rate.

C. ANOVA for GFRP composite

The purpose of the statistical ANOVA is to investigate which design parameter significantly affects the surface roughness, material removal rate and delamination factor. Based on the ANOVA, the relative importance of the machining parameters with respect to surface roughness, material removal rate and delamination was investigated to determine more accurately the optimum combination of machining parameters. The analysis is carried out for the level of significance of 5% (the level of confidence is 95%). It is observed that the factor surface roughness (Percentage contribution, p= 64.58%), material removal rate (p=59.34 %) and on delamination factor (p=61.05 %) for GFRP composite plates, and it reveals that the optimal combinations of process parameters are N (1500rpm), f (200mm/min), d (0.75mm).

1. The analysis using Taguchi method reveals that from the graph delamination factor value decrease with decreasing the feed rate and depth of cut and increasing with the spindle speed.
2. Whereas the surface roughness value decreases with decreasing the feed rate and depth of cut and decrease with increasing the spindle speed.
3. The feed and depth of cut have to be maintained at lower level and speed in medium level yields better material removal rate
4. Depth of cut and feed rate is the most significant parameter and spindle speed is the least significant parameter for milling of GFRP composite with the objective of minimizing surface roughness, and delamination factor.

 DOI : 10.18231/2454-9150.2018.0108 © 2018, IJREAM All Rights Reserved.

ISSN : 2454-9150 Vol-04, Issue-01, Apr 2018

5. Depth of cut and feed rate is the cutting parameter that presents the highest influence on surface roughness (64.48 %), on material removal rate (59.34 %) and on delamination factor (61.05 %).
6. The analysis using ANOVA reveals that the optimal combinations of process parameters are: speed =1500rpm, feed (f) = 200mm/min, Depth of cut (d) = 0.75mm.

REFERENCES

[1] Mohammed T. Hayajneh a,*, Montasser S. Tahat b, Joachim Bluhm c "A Study of the Effects of Machining Parameters on the Surface Roughness in the End-Milling Process" Jordan Journal of Mechanical and Industrial Engineering, Volume 1, Number 1, Sep. 2007.

[2] Naresh, K. Rajasekhar, P. VijayaBhaskara Reddy" Parametric analysis of GFRP composites in CNC milling machine using Taguchi method" IOSR Journal of Mechanical and Civil Engineering ,ISSN: 2278-1684 Volume 6, Issue 1 (Mar. - Apr. 2013).

[3] B.Bindu madhavi#1, S.Suresh*2"Structural Analysis Of DelaminationOf Composite Materials Using VerticalMilling Machine (GFRP)" International Journal of Computer Trends and Technology (IJCTT) – ISSN: 2231-2803, volume 4 Issue 7–July 2013.

[4] B.V.Kavada*, A.B.Pandeya, M.V.Tadavia, H.C.Jakhariaa "A Review Paper on Effects of Drilling on Glass Fiber Reinforced Plastic" 2nd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2014.

[5] K. V. Arun1*, D. Sujay Kumar2, M. C. Murugesh3 "Drilling of TiO2 and ZnS Filled GFRP Composites "Journal of Minerals and Materials Characterization and Engineering, 2012, 11, 785-789 Published Online August 2012.

[6] B.C. Routara*, A.K. Sahoo, Akshay K. Rout, A. K. Parida and J. R. Behera "Analysis of machining characteristics in drilling of GFRP composite with application of fuzzy logic approach" International Journal of Industrial Engineering Computations.

[7] Murthy B.R.N., Lewlyn L.R. Rodrigues* and AnjaiahDevineni "Process Parameters Optimization in GFRP Drilling through Integration of Taguchi and Response Surface Methodology" International Science Congress Association , ISSN 2277-2502, Vol. 1(6), 7-15, June 2012 .

[8] N. Naresh, K. Rajasekhar, P. VijayaBhaskara Reddy" Parametric analysis of GFRP composites in CNC milling machine using Taguchi method" IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684 Volume 6, Issue 1 (Mar. - Apr. 2013) .

[9] Hasan Gökkaya*"The Effects of Machining Parameters on Cutting Forces,Surface Roughness, Built-Up Edge (BUE) and Built-Up Layer (BUL) During Machining AA2014 (T4) Alloy, Journal of Mechanical Engineering 56(2010)9, 584-593

[10] SanjitMoshat, SauravDatta, AsishBandyopadhyayand Pradip Kumar Pal"Parametric optimization of CNC end milling using entropy measurement technique combined with grey-Taguchi method" International Journal of Engineering, Science and TechnologyVol. 2, No. 2, 2010 .

[11] Surinder Kumar1*; Meenu Gupta2; P.S. Satsangi3 and H.K. Sardana4"Modeling and analysis for surface roughness and material removal rate inmachining of UD-GFRP using PCD tool" International Journal of Engineering, Science and Technology Vol. 3, No. 8, 2011.

[12] M.P. Jenarthanan1*, R. Jeyapaul2 "Optimisation of machining parameters on milling of GFRP composites bydesirability function analysis using Taguchi method" International Journal of Engineering, Science and Technology Vol. 5, No. 4, 2013 .

[13] J. k. diliji, O.T. Gawaji"An Approach for Delamination in Milling ofGFRP using Finite Element Method" IPASJ International Journal of Mechanical Engineering, Volume 1, Issue 1, ISSN 2321-6441,June 2013 .

[14] G Dilli Babu1*, K. Sivaji Babu2, and B. Uma Maheswar Gowd3"Effect of Machining Parameters on Milled Natural Fiber-Reinforced Plastic Composites" Journal of Advanced Mechanical Engineering, (2013)

 DOI : 10.18231/2454-9150.2018.0108 © 2018, IJREAM All Rights Reserved.