Predictive Analysis of Machining GFRP Material by Taguchi Method

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ABSTRACT

Glass fiber reinforced plastic (GFRP) materials are replacing conventional engineering materials in many applications due to their typical properties and tailorability. Machining of GFRP is completely different compared to conventional engineering materials. Surface roughness of machined part plays a important role for the life of machined components. The operating parameters like speed, feed, depth of cut and the fiber orientation of GFRP material affects the outcome surface roughness. Taguchi method is utilized for statistical modeling and understanding the influence of operating parameters. The L16 orthogonal array is used for design of experiments. Signal to noise ratios is used to arrive at the optimal operating parameters. Regression model is made and the interaction plot of operating parameters is drawn

Key words: Surface roughness, Machining, GFRP, Taguchi method, S/N Ratio, Regression.

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INTRODUCTION

Glass fiber reinforced plastic (GFRP) materials are replacing conventional engineering materials in many applications due to their typical properties and tailorability. The tailorability of polymer composites i.e. synthesis of materials as per the need of the engineering application the properties can be enhanced by varying the ingredients in it. The excellent properties of GFRP include its high damping, high strength to weight ratio, corrosion resistance and fracture toughness. The pipes of glass fiber reinforced plastics made by filament winding process gives the option of varying the orientation of fibers in different angles. The synthesis of the FRP pipes is to near net shape but still these pipes have to be machined for dimensional accuracy. The knowledge acquired or the regular practices of machining conventional engineering materials cannot be applied for machining GFRP. The GFRP materials are being used in aircraft and automobile parts due to light weight and high specific strength. Davim, Mata et al [1] have used statistical method to study the variation in surface roughness induced by machining at different operating conditions.

The machining of fiber reinforced plastic poses lot of problems because the fibers are delaminated, pulled out, debonded from their matrix, powder like chips formed and burning. These side effects cause potential threats for inferior surface quality. Surface quality is also a determining factor for component life in assembly and fracture toughness. Bhatnagar,Ramkrishna et al.[2] have studied regarding the dimensional accuracy of machined GFRP laminate materials. Everstine and Rogers [3] have developed a analytical concept for machining FRP. The fibers were laid in parallel direction in the resin and the deformation along the plane was studied. Koing et al [4] found that the surface roughness of machined FRP is typical as the protruding fiber tips added up for surface roughness. Thus the values of surface roughness are more robust in case of metals. Velayudham. A et al [5] used wave transforms for studying drilling characteristics of excess volume of the fraction of fibers in GFRP composites.Mohan.N.S.et al [6] concentrated their work on cutting force parameter for machining GFRP material and analyzed the reading with statistical package.Ramkumar.J.et al [7] worked on the vibrational effects of machined part. The induced vibrational effect reduced cutting force, tool wear and temperatureWang and Zhang [8] studied the orthogonal cutting on the unidirectional GFRP material. . Aravindan et al [9] synthesized the GFRP pipes by hand layup process and evaluated the machinability. Sreejith et al [10] used carbide cutting tool and found that the feed force has major effect on tool wear and surface roughness. The effective hardness of the tool was also determined. Paulo davim and Mata [11 & 12] came up with a newer method of defining the parameter for machineability index. They used diamond point cutting tool and cemented carbide for machining hand laid up GFRP pipes. The cost of polycrystalline diamond point cutting insert is high but performance was found to be superior compared to cemented carbide tool.

MATERIALS AND METHODS

Machine Tool

Slant bed CNC machine tool of M Tab make was utilized was machining. This machine suited well to machine under low and high cutting speed with various feed rates and depth of cut. The cutting insert was of cemented carbide of widia make of triangular shape.

Work material

The GFRP pipes were manufactured at a small scale factory in peenya industrial area Bangalore. Filament winding method was used to get different orientation of glass fibers wound over the resin matrix. The wetted e-glass fibers with resin are wound over a mandrel which is rotating around the spindle while the fiber in tension is fed from the horizontally traversing carriage. The pattern of winding is helical for which different orientations or angles can be formed varying the traversing speed of the carriage. The pipes of fiber orientations 30^o, 50^o, 70^o, 90^o were made and cured. The pipes had the dimensions of length 150 mm, outer dia. of 50mm and inner dia. of 30 mm.

Surface roughness measurement

Surface roughness was measurement was done using Talysurf tester equipment. The surface roughness is measured in terms of Ra values in microns. Ra is the average surface roughness value for the deviations from the mean the line.

Process parameters and plan of experiments

The process parameters chosen for conducting experiments are cutting speed, feed rate, depth of cut and fiber orientation of work material at four different levels shown in table 1.

Table 1 Table for process parameters and levels.

Levels	Process parameters			
	Speed (m/min)	Feed (mm/rev) B	Depth of cut (mm) C	Fiber orientation D
Level 1	30	0.04	0.4	30^o
Level 2	50	0.05	0.6	50^o
Level 3	70	0.06	0.8	70^o
Level 4	90	0.07	1	90^o

RESULTS AND DISCUSSIONS

The experiments were conducted as per the plan of experiments of Taguchi's orthogonal array L16.Taguchi approach of orthogonal array reduces large number of trials.

This is a robust method for reducing the variability in the outcome of the response. The response chosen is surface roughness which is measure of machineability.

Table 2 Design Matrix for Experimental outcomes and S/N ratios.

Speed(m/min)	Feed(mm/rev)	Doc(mm)	fiber angle	Ra(μm)	S/N Ratio Ra
30	0.04	0.4	30	3.1682	-10.0163
30	0.05	0.6	50	3.3654	-10.5407
30	0.06	0.8	70	3.8596	-11.7308
30	0.07	1.0	90	4.2583	-12.5847
50	0.04	0.6	70	4.5231	-13.1087
50	0.05	0.4	90	3.4123	-10.6609
50	0.06	1.0	30	3.5563	-11.0200
50	0.07	0.8	50	3.8754	-11.7663
70	0.04	0.8	90	3.7102	-11.3879
70	0.05	1.0	70	4.0423	-12.1326
70	0.06	0.4	50	2.9895	-9.5120
70	0.07	0.6	30	2.5423	-8.1045
90	0.04	1.0	50	3.4523	-10.7622
90	0.05	0.8	30	3.8754	-11.7663
90	0.06	0.6	90	3.7541	-11.4901
90	0.07	0.4	70	3.1682	-10.0163

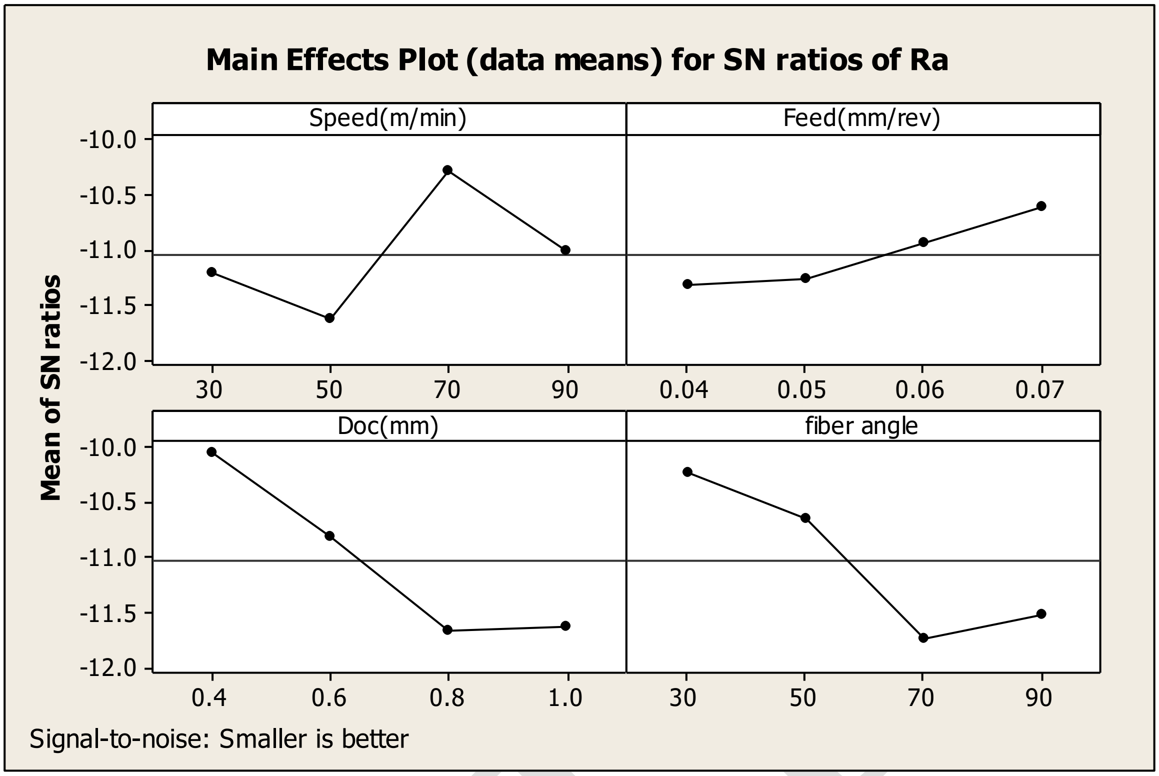

Fig 1: Main Effects Plot for SN ratios of Surface Roughness.

Table 3 Response Table for Signal to Noise Ratios (Smaller is better)

Level	Speed(m/min	Feed(mm/rev)	Doc(mm)	Fiber angle
1	-11.22	-11.32	-10.05	-10.23
2	-11.64	-11.28	-10.81	-10.65
3	-10.28	-10.94	-11.66	-11.75
4	-11.01	-10.62	-11.62	-11.53
Delta	1.35	0.70	1.61	1.52
Rank	3	4	1	2

The surface roughness is the most vital and characteristic feature of machining of GFRP material. The signals to noise ratio gives the measure for quantizing the significance of operating parameters. The surface roughness outcome as to be kept minimal therefore the condition of S/N ratio used for minimum surface roughness is smaller the better. The analysis was carried out using Minitab software. The design matrix of experimental outcome along S/N ratio is tabulated in Table 2. The mean effects plot for SN ratios of Ra is shown in fig.1

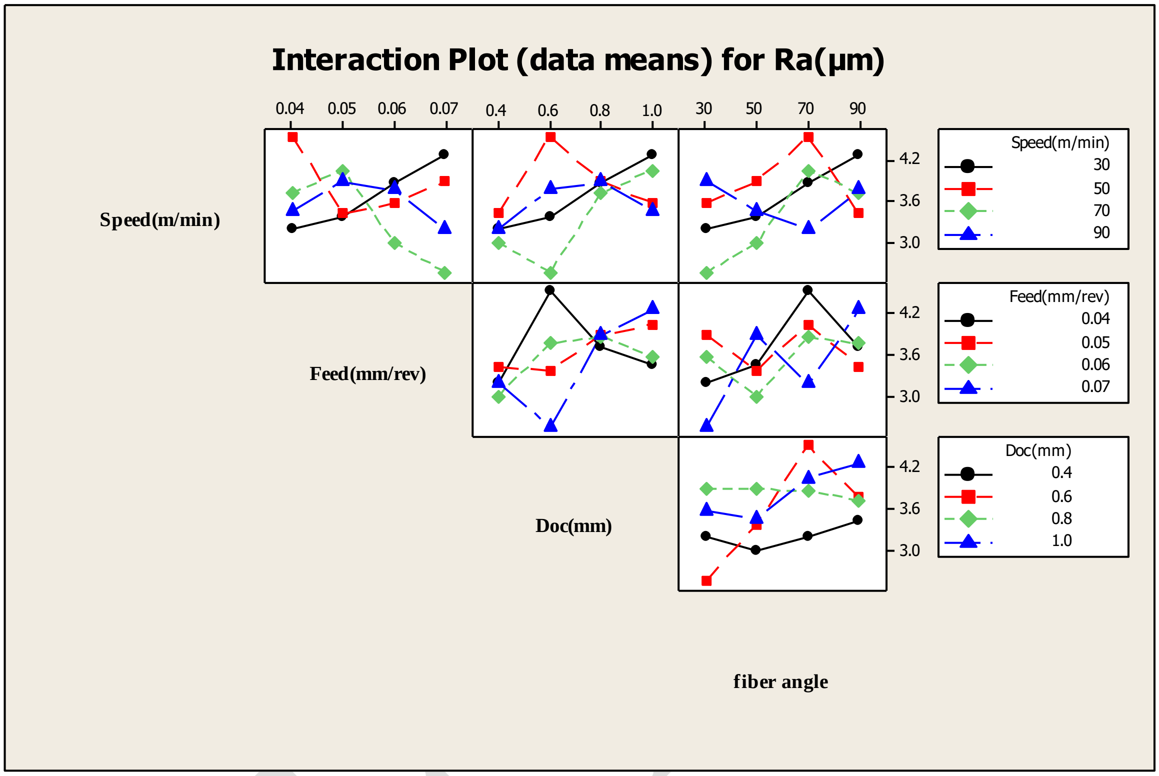

Fig 2: Interaction Plot for Surface Roughness.

The interaction plot for surface roughness is shown in fig.2.The operating parameters speed, feed, depth of cut and fibre orientations are plotted on x axis and the response parameter surface roughness is plotted on y axis.

Regression Analysis:

Ra(µm) versus Speed(m/min), Feed(mm/rev), Depth of cut (mm) and fiber angle (degrees)

The regression equation is
Ra(µm) = 2.97 - 0.00411 Speed(m/min) - 8.91 Feed(mm/rev) + 1.11 Doc(mm)
+ 0.00986 fiber angle

Optimality Prediction

The Optimal operating parameters and the resulting output parameter is

Optimum Speed (m/min)	Optimum Feed (mm/rev)	Optimum Depth of cut (mm)	Optimum Fiber orientation	Optimum Surface Roughness. Ra(μm)
70	0.07	0.4	30	2.461

CONCLUSION

From the experimental investigations and Taguchi analysis the following conclusions can be made

- Depth of cut is the major influencing factor for the output parameter surface roughness followed by fiber angle, cutting speed and feed rate of machining.
- The cut ends of the fiber are responsible for higher value of surface roughness.
- The highest value of S/N ratio gives the optimum values of operating parameters.
- The optimum operating parameter values for cutting speed is 70 m/min, feed is 0.07mm/rev, depth of cut is 0.4mm and fiber angle 30 degrees.

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