Optimization of Parameters in Turning of UD-GFRP Cryogenic Condition with Taguchi Method

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Abstract - *Cryogenic condition of composites is very difficult for machining due to in homogeneous and anisotropic atmosphere and it require unique cutting tools. At present machining of composite is importance of faster and other light weight application. This work is going to examine in the cryogenic condition machining of tool wear, quality of the surface and forces generated in the various stages of inputs given to the machining of UD-GFRP composite. i.e., cutting speed, depth of cut and feed rate, environmental parameters i.e., cryogenic condition, cutting tool parameters i.e., tool geometry, tool material, work piece material parameters i.e., UD-GFRP composite materials .The aim to study the impact of cutting velocity, feed rate and depth of cut on apparatus tool wear, surface roughness and cutting force generated, then to set up a connection between them. The investigated values are obtained minimize cutting forces, surface roughness and tool wear. It is believed that the used method provides a robust way of looking at the optimum parameter selection problems.*

Key Words: UDGFRP composites, cryogenic condition, cutting parameters, Polycrystalline diamond (PCD) tool, L9 Taguchi optimization and surface roughness.

1. INTRODUCTION

Many parts are of made up of carbon fiber reinforced plastics (CFRP) and are regularly delivered close to required shape. Turning, processing and boring, notable from the metal machining, additionally have a place with the much of the time utilized machining forms for CFRP parts. CFRP machining is of absolute significance for beginning sequential creation of high accuracy parts.

Cryogenic machining, as substitute to conventional machining and has to enhance machinability of hard-to-cut the materials like assort aluminum, titanium and abrasive composites. Maximum temperatures occurred throughout machining of such materials may manipulate tool wear, surface quality and geometrical accurateness of the machined work piece. One of the aims of the cryogenic machining is to take out heat generated for the period of machining at critical zone and getting well again surface roughness. In cryogenic machining, tremendous cold liquefied gases of oxygen, nitrogen, hydrogen or helium are used as coolants. Among such liquefied gases, liquid nitrogen is the most used one because it is abundant,

Machining of glass fiber composite is a major crisis, since high hardness and inert nature. Because of their dissimilar applications, the need for FRP machining has not been fully eliminated. For a just right machining procedure, it is very significant to proper selection of cutting parameters like cutting speed, geometry of cutting tool and type of tool material. The mechanism of machining GFRP is quite different from metals because of non-homogenous, anisotropic nature

2. LITERATURE SURVEY

Examination and explores the effect of utilizing cryogenic fluid nitrogen and least amount greasing up coolants on the boring quality in GLARE 2B11/10-0.4 fiber metal covers and pneumatic force on the gap quality. The outcomes show that utilizing cryogenic and least amount grease coolants can significantly diminish leave burr arrangement K. Giasin et.al[1]. Milling performance of CFRPs in cryogenic medium was done and machining performance evaluated based on the resultant force of delaminating feature, roughness of surface, and damage of surface. Furthermore, the pressure of cryogenic coolant on the tensile properties, the microstructure of surface, and machined surface of the CFRP laminates were analyzed with scanning electron microscopy (SEM). SezerMorkavuka et.al. [2] The exploratory investigation on front line span of boring tool, external corner wear of boring tool, trust power, force, delaminating component and distance across blunder of penetrated gap, are introduced and dissected contrasting dry boring and cryogenic cooling of CFRP composite material. The discoveries show that cryogenic cooling pro fondly affects diminishing the front lined just in boring tool and external corner wear; it additionally helps upgrading the surface trust worth in qualities of delivered opening T.Xia1&Y.Kaynak et al [3]. The cryogenic investigation presents major device math examinations dependent on symmetrical cutting of unidirectional CFRP-material. The examination has demonstrated the influence of the fiber direction and device calculation on an ensuing report breaks down the surface unpleasantness just as the presence of the chip root Subsurface harms are assessed utilizing micrograph segments. Accomplished work piece quality has been broke down in another ensuing investigation M. Henerichs et al. [4].

3. METHODOLOGY

This paper deals with the output parameter of surface roughness, tool wear and cutting forces, we have considered input parameters as given table1.The Glass fiber reinforced plastic (GFRP) rods of 20mm diameter are produced by pultrusion process. The fabricated GFRP composite rods are cut into small segments of length 150 mm and machined in the CNC machine by changing input parameters (speed, feed, and depth of cut) and the cutting forces is estimated by the dynamometer setup. After each trial the wear of the tool is estimated by using the tool maker's microscope. The composite rods are then taken into the surface roughness tester to find out surface roughness values. These resultant parameters are assessed by using the Taguchi and Minitab programming to find economical values with respect to given input values

Table -1: The fixed Process Parameters and levels of variable Process parameters

Input parameters	stage 1	Stage 2	Stage 3
Depth of the cut in mm	0.5	1	1.5
Tool Feed in mm/rev	0.05	0.1	0.15
Cutting speed in rpm (m/min)	1000 (1047.19)	1200 (1256.63)	1500 (1570.79)
Tool material	PCD	PCD	PCD
Tool rake angle	6	6	6
Cutting Environment	Dry/Wet and Cryogenic	Dry/Wet and Cryogenic	Dry/Wet and Cryogenic

The Parameters are: speed of cutting, rate of feed and depth of cut, Environment parameters: Cryogenic condition, Cutting tool parameters: tool geometry, tool material, Work piece material: UD-GFRP composite materials

Cutting fluids

Cryogenic physics is a branch of physics which deals with the production of very low temperatures and their effect on matter it addresses both aspects of attaining low temperatures which do not naturally occur on Earth, and of using them for the study of nature or the human industry. Liquid nitrogen - which is colorless, odorless and tasteless and eco friendly to environment and used for machining of hard metal and ceramics composites for better surface finishing. In this research to get the behavior of machining a of composite under this condition, here liquid nitrogen is used for machining of composite and examine the various parameters .In general Liquid nitrogen has– 196 °C [– 320 °F].

4. Experimentation

Here the glass fiber reinforced composite rod in turning was done with the different machinability trials. The cutting tool used is PCD inserts shown in Figure 5 and its description furnished in Table 2. The GFRP bar of 20mm diameter, 150 mm long jobs prepared and experimented in SUPER JOBBER 500 CNC (SIEMENS 802 D SL) turning center figure 1). The UD-GFRP composite specifications furnished in Table 4. Figure 7 depicts the prepared job setting on CNC center. The Figure 3 exhibits the CNC turning facility which employed for executing the experimentations., These values are analyze by MINI Tab soft ware individually, at the last step of research did on comparison of all the values

Fig -1 CNC SUPER JOBBER 500 CNC Turning center

Fig -2 Tool maker's microscope

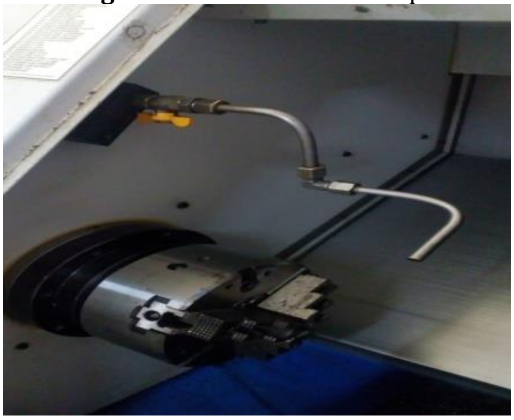

Fig -3 Coolant supply setup in machine

Fig-4 Mitutoyo Surface Roughness tester

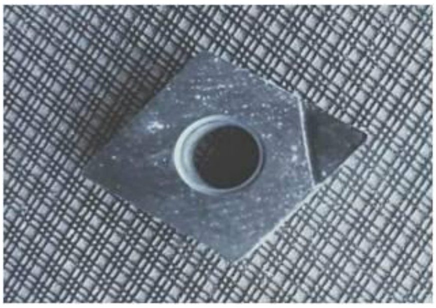

Fig-5 The polycrystalline diamond tool inserts

Fig-6 CNC Lathe dynamometer setup

Fig-7 CNC machine setup

Fig-8 Liquid nitrogen

Fig-9 Machined Components

The cryogenic machining environment helps in extends tool life and save the UD-GFRP composite from thermal damages. The flow rate maintained at 1liter per minute. The Mitutoyo make tester employed for measuring surface peaks on machined work pieces. The surface roughness tester shown in the Figure 4. The surface roughness was calculated average on machined surface in micrometer. The wear property of the tool was investigated with tool maker's microscope Figure

Table -2: Specification of PCD tool [1]

Properties of PCD tool.	
Clearance angle	6o
Grade	M10
Density	3.80e4.50 g/cm3
Hardness	1600 Vickers kg/mm2
Young's modulus	800e900 GPa
Compressive strength	7000e8000 N/mm2
Cutting edge inclination angle top	6^0
Tool rake angle	6^0

Table -3:. Properties of Composite bar [1]

Description of composite	Quantity/ Specification
Composite's Strength on Compression	600 N/mm2
Youngs Modulus of Composite	320 N/mm2
Absorption Moisture/Water absorption	7x10-2%
Fiber orientation	unidirectional

Epoxy resin content (by weight)	25 ± 5 %
wt.% of Glass Fiber contribution	75 ± 5%
Composite's Strength on Tensile	650 N/mm2
Composite's Strength on Shear	255 N/mm2
Agent of Reinforcement,	Roving: E- Glass

Table -4:. Orthogonal array (L9)of Taguchi along with assigned value

S N o.	Speed (rpm)	Feed (mm /rev)	Depth of cut(mm)	Tool material	Cutting Environment	Tool rake angle
1.	1000	0.05	0.5	PCD	Cryogenic	6
2	1000	0.1	1	PCD	Cryogenic	6
3	1000	0.15	1.5	PCD	Cryogenic	6
4	1200	0.05	1	PCD	Cryogenic	6
5	1200	0.1	1.5	PCD	Cryogenic	6
6	1200	0.15	0.5	PCD	Cryogenic	6
7	1500	0.05	1.5	PCD	Cryogenic	6
8	1500	0.1	0.5	PCD	Cryogenic	6
9	1500	0.15	1	PCD	Cryogenic	6

The results were conducted with the cryogenic condition and examination is done by utilizing Minitab programming. The impacts of speed, feed, depth of cut and there collaborations on its surface quality (roughness), tool wear and cutting forces has been created utilizing multiple regression model. The analysis of variance (ANOVA) Taguchi L9 orthogonal array has been applied to consider the impact of the input parameters on its reaction, surface harshness, Tool wear and cutting forces

5. RESULTS AND DISCUSSION

The analysis of variance (ANOVA) Taguchi L9 orthogonal array has been applied to consider the impact of the input parameters on its reaction, surface harshness, Tool wear and cutting forces

Table -5 Experimental Observations under Cryogenic machining condition

Exp No.	Tool wear response Average $V_{b\,(Avg)}$ mm	Surface response Average In µm R_a	Cutting Force(N) Average In F_{Avg}
1	0.138	4.958	14
2	0.981	5.269	14
3	0.165	5.126	15
4	0.056	5.512	16
5	0.195	4.648	17
6	0.468	5.95	18
7	0.044	5.101	19
8	0.195	4.265	20
9	0.986	5.901	20

5.1 Taguchi Analysis: Surface response (µm) versus Speed, Feed, Dept of cut

The effect of cryogenic condition on Surface response (µm) versus Speed, Feed, Dept of cut, The below figure Fig 10 explains the main effecting parameter of surface roughness for different speed, Feed and depth of cut is as Speed for 1200 rpm, feed 0.05mm/rev and depth of cut 1.0mm gives economical surface roughness meanwhile it will followed by speed 1000 rpm, feed 0.10mm/rev and depth of cut 1.5mm give moderate surface roughness and speed 1500rpm , feed 0.15mm/rev and depth of cut 0.5mm gives very rough surface , means the above sequence will influences the more. From overall performance got good surface fining and observed that no fibers are pulling out while using cryogenic condition. The exact vales are shown in Table.6.

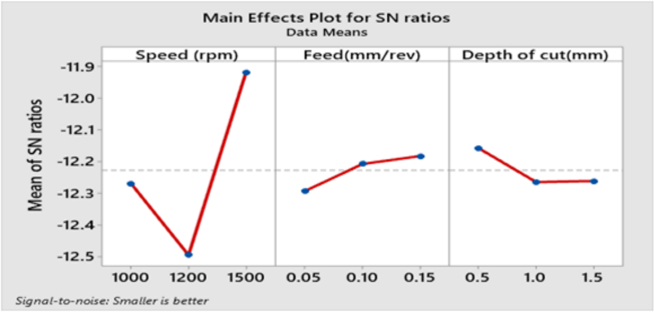

Fig-10. Main Effects plot for S/N ratios

Table -6:. Response Table for Signal to Noise Ratios

Level	Speed (rpm)	Feed(mm/rev)	Depth of cut(mm)
1	-12.27	-12.29	-12.16
2	-12.49	-12.21	-12.26
3	-11.92	-12.18	-12.26
Delta	0.58	0.11	0.11
Rank	1	2	3

Table -7: Response Table for Means

Level	Speed (rpm)	Feed(mm/rev)	Depth of cut(mm)
1	4.107	4.12	4.056
2	4.215	4.079	4.109
3	3.945	4.069	4.102
Delta	0.27	0.05	0.053
Rank	1	3	2

Here Response Table.7 for Means of means given according to the figures 11, the three experimental values of surface roughness which are took by only 1000rpm i.e. surface roughness of all 1000rpm speed were calculated. The below figure Fig 11 explains the means of mean parameter of surface roughness for different speed, Feed and depth of cut is as Speed for 1500 rpm, feed 0.15mm/rev and depth of cut 0.5mm gives economical surface roughness meanwhile it will followed by speed 1000 rpm, feed 0.1mm/rev and depth of cut 1.0mm gives moderate surface roughness and speed1200, feed 0.05mm and depth of cut 1.0 gives very rough surface, means the above sequence will influences the economical to higher order. From this overall performance the preferable for getting good surface roughness is Speed for 1500 rpm, feed 0.15mm and depth of cut 0.5mm

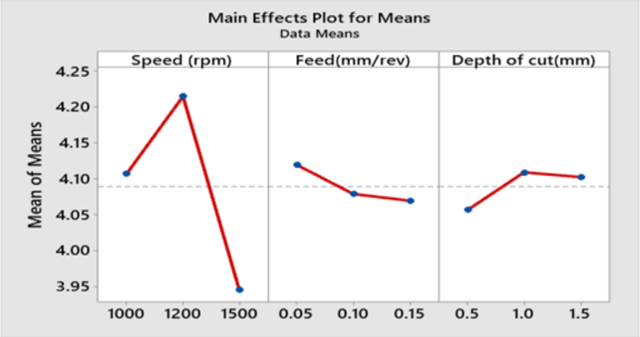

Fig-11. Main Effects Plot for Means

5.2 Taguchi Analysis: Tool wear response versus Speed, Feed, Dept of cut

The below figure Fig 12 explains the main effecting parameter of Tool wear response for different speed, Feed and depth of cut is as Speed for 1000 rpm, feed 0.15mm/rev and depth of cut 1.0mm gives economical tool wear response meanwhile it will followed by speed 1000 rpm, feed 0.1mm/rev and depth of cut 0.5mm gives moderate tool wear and speed1200rpm, feed 0.05mm/rev and depth of cut 1.5mm gives very high tool wear. From this overall performance the preferable for getting good less tool wear is Speed for 1000 rpm, feed 0.15mm/rev and depth of cut 1.0mm and observed very less tool wear is happening while using cryogenic machining.

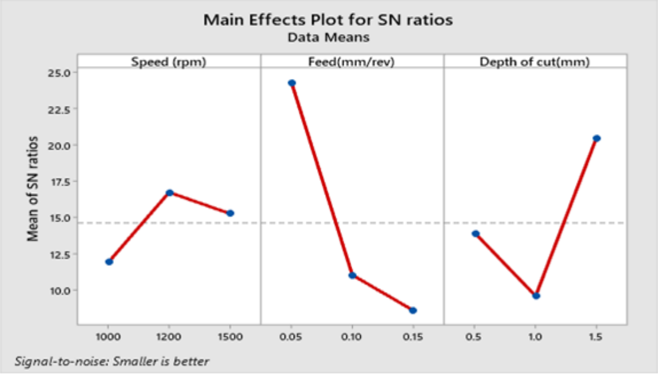

Fig-12. Main Effects plot for S/N ratios

Table -8: Response Table for Signal to Noise.

Level	Speed (rpm)	Feed (mm/rev)	Depth of cut(mm)
1	11.89	24.31	13.88
2	16.71	10.99	9.54
3	15.25	8.55	20.43
Delta	4.82	15.76	10.88
Rank	3	1	2

Table -9 : Response Table for means of means.

Level	Speed (rpm)	Feed (mm/rev)	Depth of cut(mm)
1	0.397	0.070	0.235
2	0.21	0.411	0.611
3	0.352	0.477	0.112
Delta	0.187	0.407	0.498
Rank	3	2	1

Here Response Table.9 for Means of means given according to the figures13, the values derived by the means of the means the calculation shown. According to given figure 13. Tool wear response for different speed, Feed and depth of cut is as Speed for 1200 rpm, feed 0.05mm/rev and depth of cut 1.5mm gives economical tool wear response meanwhile it will followed by speed 1500 rpm, feed 0.1mm/rev and depth of cut 0.5mm gives moderate tool wear and speed1000, feed 0.15mm/rev and depth of cut 1.0mm gives very high tool wear, means the above sequence will influences the more. From this overall performance the preferable for getting good less tool wear is Speed for 1200 rpm, feed 0.05mm/rev and depth of cut 1.5mm.

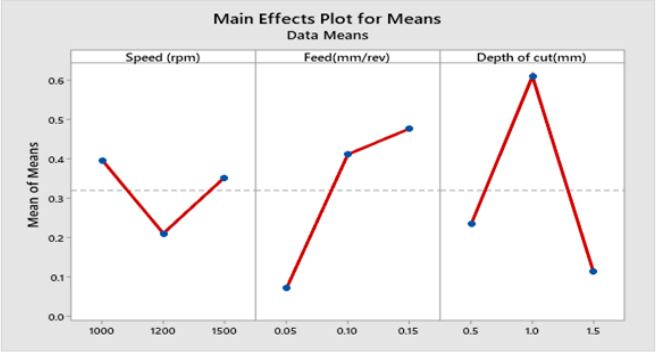

Fig-13. Main Effects Plot for Means

5.3 Taguchi analysis for cutting force Taguchi Analysis: Cutting Force (N) versus Speed, Feed, Depth of cut

The below figure Fig14 explains the main effecting parameter of cutting force (N) response for different speed, Feed and depth of cut is as Speed for 1500 rpm, feed 0.15mm/rev and depth of cut 0.5mm gives economical cutting force response meanwhile it will followed by speed 1200 rpm, feed 0.1mm/rev and depth of cut 1.0mm gives moderate cutting force and speed1500rpm, Feed 0.05mm/rev and depth of cut 1.5mm gives very high cutting force, means the above sequence will influences the more. From this overall performance the preferable for getting good less cutting force is Speed for 1500 rpm, feed 0.15mm and depth of cut 0.5mm

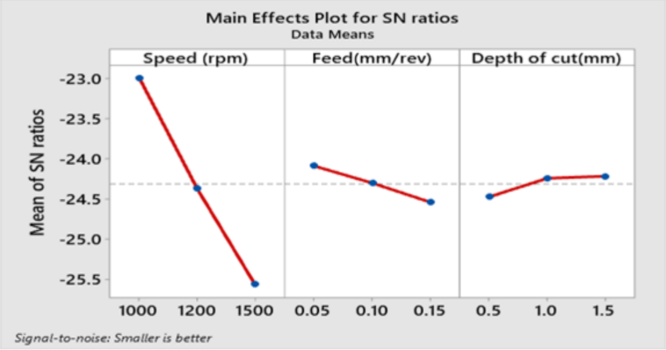

Fig-14 Main Effects plot for S/N ratios

Response Table 11 for Means of means given according to the figures 15, the values derived by the means of the means the calculation are taken by table tool wear of all the 1000rpm were taken average The below figure Fig 15 explains the main effecting parameter of cutting force (N)response for different speed, Feed and depth of cut is as Speed for 1000 rpm, feed 0.05mm/rev and depth of cut 1.0mm gives economical cutting force response meanwhile it will followed by speed 1200rpm, feed 1.0mm/rev and depth of cut 1.0mm gives moderate cutting force and speed 1500 rpm, feed 0.15mm/rev and depth of cut 0.5mm gives very high cutting force, means the above sequence will influences the more. From this overall performance the preferable for getting less cutting force is Speed for 1000 rpm, feed 0.05mm and depth of cut 1.5mm.

Table -10 : Response Table for Signal to Noise Ratios

Level	Speed (rpm)	Feed (mm/ rev)	Depth Of Cut (mm)
1	-22.99	-24.09	-24.48
2	-24.37	-24.3	-24.24
3	-25.57	-24.54	-24.22
Delta	2.58	0.45	0.26
Rank	1	2	3

Table -11 : Response Table for Signal to Noise Ratios

Level	Speed (rpm)	Feed (mm/ rev)	Depth of Cut (mm)
1	14.11	16.11	16.89
2	16.56	16.56	16.44
3	19	17	16.33
Delta	4.89	0.89	0.56
Rank	1	2	3

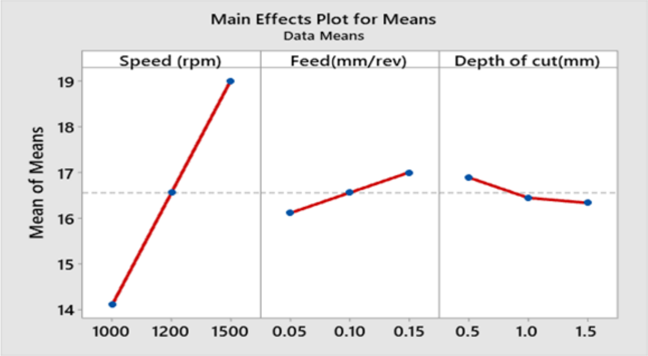

Fig-15. Main Effects Plot for Means

6. CONCLUSIONS

The investigation on some aspects of machinability such as surface roughness and cutting force and tool wear during turning of GFRP composite materials and considering as Polycrystalline diamond tool (PCD) as cutting tool based on the experimental results, the following conclusions are drawn within the range of parameters selected.

As concern of Surface roughness parameter the better results got when Speed for 1200 rpm, feed 0.05mm/rev and depth of cut 1.0mm used. In UG-GFRP composites the surface roughness is highly influenced by Feed rate and it got rank 1 and 2nd depth of cut and 3rd speed parameters. As concern of Tool wear parameter Speed for 1000 rpm, feed 0.15mm/rev and depth of cut 1.0mm gives less tool wear values and feed rate influenced more. The most helpful parameter for getting less cutting force according to taguchi L9 orthogonal array is Speed for 1500 rpm, feed 0.15mm/rev and depth of cut 0.5mm. The cutting forces are produced high rate when the 1000rpm feed 0.05mm/rev and depth of cut 1.5 mm gives very high cutting force, in this states that we conclude that when speed is increased the cutting forces are reduced.

- Under this cryogenic condition of machining observed that no fibred are pulling out while machining.
- Getting better surface roughness as compare to normal wet machining.
- Tool life increased by using cryogenic machining because of tool maintain less temperature while in operation.

The future scope of work includes the following:

The machined of work restricted to Cryogenic condition only it may be further extended to comparison of dry, wet and cryogenic condition. The number of machining parameters can be extended hence; the data base can be improved by extensive experimentation.

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