INVESTIGATION OF SURFACE FINISH AND MRR DURING ABRASIVE ASSISTED DRILLING ON POLYMER MATRIX COMPOSITE MATERIAL.

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Abstract - ***This report is concerned with investigating the Surface finish when drilling POLYMER MATRIX COMPOSITE (E-Glass) with HSS drill. This study included drilling of PMC with supply of Sic abrasive, Alumina Oxide Abrasive having grain size 800, 1000, 1200 mesh size through abrasive slurry system & with Coolant. Abrasives not only used for cooling purpose but also increases the surface finish, MRR and reduce tool wear. Experiments were conducted on a CNC Drilling machine. Taguchi is applied for executing the planning of experiments. The drilling parameters namely Feed rate (mm/min) ,Spindle speed (rpm) ,Type of abrasive grain size ,Slurry Concentration ,Type of Abrasive (Silicon Carbide, Alumina oxide), were optimized using multiple performance characteristics for Surface Finish. The result shows that the feed rate, Type of Abrasive & slurry concentration are the most significant factors which affect the Surface finish in the drilling can be effectively improved by using this approach***

Key Words: *Abrasives, ANOVA, Drilling, Taguchi Technique, Polymer Matrix Composite material E-Glass , Surface roughness, MRR.*

1. INTRODUCTION

Drilling is one of the most fundamental machining processes. It is most frequently performed in material removal and is used as a preliminary step for many operations such as reaming, tapping and boring. It is moving toward high speed applications for productivity enhancement. Drilling is a process of producing round hole in solid material or enlarging existing hole with the use of multi-point cutting tools called drill or drill bits. Various cutting tools are 297blind hole in a solid material. It has found that high production machining and drilling with high cutting velocity, feed and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature which reduces accuracy and tool life. Drilling is an essential operation in the assembly of the structural frames of automobiles and aircrafts. The life of a joint can be critically affected by the quality of the drilled holes. The growing demand for higher productivity, product quality and overall economy in manufacturing by machining, grinding and drilling, particularly to meet the challenges thrown by liberalization and global cost competitiveness, insists high material removal rate and high stability and long life of the cutting tools. However, high production machining and grinding with high cutting velocity, feed and depth of cut is inherently associated with generation of large amount of heat and high cutting temperature. Such high cutting temperature not only reduces dimensional accuracy and tool life but also impairs the surface finish of the product. One estimate is that 75% of all metal-cutting material removed comes from drilling operations. Drilled holes are characterized by their sharp edge on the entrance side and the presence of burrs on the exit side (unless they have been removed).

We all know that the 20th century has witnessed revolutions in a number of fields like computer,
Radar, space, missiles, etc. but the most interesting changes have taken place in the area of polymer matrix composites. In the literature review we will review the surface roughness and material removal rate, Taguchi technique.

2. LITERATURE REVIEW

J.Pradeep Kumar analyzed that to utilize Taguchi method to investigate the effects of drilling parameters on surface roughness, tool wear by weight, material removal rate and hole diameter error in drilling of OHNS material using HSS spiral drill. Orthogonal arrays of Taguchi, the Signal–to-Noise (S/N) ratio, the analysis of variance (ANOVA), and regression analysis are employed to analyze the effect of drilling parameters on the quality of drilled holes. A series of experiments based on L18 orthogonal array are conducted. The experimental results are collected and analyzed using commercial software package MINITAB 13. Linear regression equations are developed with an objective to establish a correlation between the selected drilling parameters with the quality characteristics of the drilled holes. The predicted values are compared with experimental data and are found to be in good agreement [1].

Yogendra Tyagi investigated that the drilling of mild steel with the help of CNC drilling machine operation with high speed steel by applying Taguchi methodology has been reported. The Taguchi method is applied to formulate the experimental layout to ascertain the element of impact each optimum process parameters for CNC drilling machining with drilling operation of mild steel. A L9 array, Taguchi method and analysis of variance (ANOVA) are used to formulate the procedure tried on the change of parameter layout. The available material study in focuses optimization of CNC Drilling machine process parameters to provide good surface finish as well as high material removal rate (MRR).The surface finishing and material removal rate have been identified us quality attribute and are assumed to be directly related to productivity. The selection of optimal machining parameters i.e., spindle speed, depth of cut and feed rate) for drilling machine operations was investigated in order to minimize the surface roughness and to maximize the material removal rate [2].

Arshad Noor Siddiquee had focused on optimizing deep drilling parameters based on Taguchi method for minimizing surface roughness. The experiments were conducted on CNC lathe machine using solid carbide cutting tool on material AISI 321 austenitic stainless steel. Four cutting parameters such as cutting fluid, speed, feed and hole-depth, each at three levels except the cutting fluid at two levels were considered. Taguchi L18 orthogonal array was used as design of experiment. The signal-to-noise (S/N) ratio and the analysis of variance (ANOVA) was carried out to determine which machining parameter significantly affects the surface roughness and also the percentage contribution of individual parameters. Confirmation test was conducted to ensure validity of the test result. It is observed that the surface finish for deep drilling process can be improved effectively through this approach [3].

B.V.Kavad had studied that drilling is an important process for making and assembling components made from Glass Fiber Reinforced Plastic (GFRP). Various processes like conventional drilling, vibration assisted drilling and ultrasonic assisted drilling have been attempted in order to maintain the integrity of the material and obtain the necessary accuracy in drilling of GFRP. This paper attempts to review the influence of machining parameter on the de-lamination damage of GFRP during drilling. In conventional machining feed rate, tool material and cutting speed are the most influential factor on the de-lamination hence machining at higher speed, harder tool material and lower feed rate have lesser de-lamination of the GFRP. Vibration assisted drilling and Ultrasonic assisted drilling have lesser thrust and hence lesser de-lamination compared to conventional drilling, which indicates that both vibration assisted drilling and Ultrasonic assisted drilling are more appropriate for drilling of GFRP [4].

B. Ramesh investigated that a non laminated Glass Fiber Reinforced Plastic (GFRP) composite manufactured by pultrusion process was drilled with a coated cemented carbide drill. The thrust force and torque during drilling were acquired through piezoelectric dynamometer and damage factor was measured using metallurgical microscope. Taguchi's orthogonal array and analysis of variance (ANOVA) were employed to study the influence of process parameters such as feed and spindle speed on thrust force, torque and damage factor. The optimum level of process parameters towards minimum thrust force, minimum torque and lower damage factor were obtained to achieve defect controlled drilling of GFRP composites. Correlations for thrust force, torque and damage factor with process parameters were established using statistical software MINITAB 15. Among the process parameters examined, feed significantly influences both the thrust force and torque with 88.52% and 92.83% respectively whereas the influence of spindle speed on the above was relatively insignificant. The influence of feed and spindle speed on damage factor at both entrance and exit of the work piece was insignificant [5].

3. MACHINING SETUP

For the entire experiment Computer Numerical Machine (FAMUP Machining Centre) was used shown in fig 1. The abrasive slurry of Silicon Carbide and Alumina Oxide of grit size 800, 1000, 1200 was cutting fluid for experimentation. The slurry was used with varying concentration of 20%, 25%, and 30%. The work material used for the experimentation is Polymer matrix composite (E-Glass). Then surface roughness of machined surface was measured with the help of Mtiutoyo SJ-201P for all the machined samples. Average surface roughness "Ra" was measured.

Fig -1: Experimental set-up

3.1 Polymer Matrix Composite

A composite material contains more than one component. The composite material is mostly related to polymer composites, in which the polymer is the matrix and the fibers are reinforcements. Glass fibers are the most common fibers of all reinforcing fibers for polymeric matrix composites (PMC). It is when the resin systems are combined with reinforcing fibers such as glass that exceptional properties can be obtained. The resin matrix spreads the load applied to the composite between each of the individual fibers and also protects the fibers from damage caused by abrasion and impact. High strength and stiffness, ease of molding complex shapes, high environmental resistance all coupled with low densities, make the resultant composite superior to metals for many application . The composition of the work piece is shown in Table 1.

Table -1 Chemical composition of E-Glass

Composition	Percentage
SiO_2	55.2
$Al_2 O_3$	8
Ca O	18.7
Mg O	4.6
Na_2O	0.3
K_2O	0.2
B_2O	7.3

3.2 Abrasive

A material of extreme hardness that is used to shape other materials by a grinding or abrading action .Abrasive materials may be used either as loose grains, as grinding wheels, or as coatings on cloth or paper. They may be formed into ceramic cutting tools that are used for machining metal in the same way that ordinary machine tools are used. Because of their superior hardness and refractory properties, they have advantages in speed of operation, depth of cut, and smoothness of finish. The manmade abrasives are silicon carbide, Aluminum oxide, Cubic boron nitride.

4. EXPERIMENTATION

In the present investigation, five different process parameters have been selected as already discussed. The tool material factor has two levels whereas all other parameters such as depth of cut, table speed, grit size and slurry concentration have three levels each. As per the requirements of the study, L18 orthogonal array has come out as one of the possible solutions for designing the experiments. Here, the term 'signal' represents the desirable value (mean) and the 'noise' represents the undesirable value (standard deviation). The percentage contribution of various process parameters on the selected performance characteristic can be estimated by performing analysis of variance test (ANOVA). The five process parameters are considered including type of abrasive, feed rate, speed of spindle, abrasive grit size, slurry concentration are shown in table 3.1. Taguchi's robust design of experiments (DOE) methodology was used to plan the experiments statistically. Minitab 16 has been used to model the effect of process parameters. The signal to noise ratio (S/N ratio) is obtained using Taguchi's methodology.

Table -2 Control Parameters and Their Levels

Factors	Levels	Level 1	Level 2	Level 3
Type of Abrasive (A)	2	$Al_2 O_3$	Si C	
Feed Rate (B)	3	100	200	300
Speed of Spindle (C)	3	1500	2000	3000
Abrasive size (D)	3	800	1000	1200
Slurry const. (E)	3	15%	25%	35%

In this research, five different process parameters with three levels have been selected. As per Taguchi, L18 orthogonal array has come out as one of the possible solutions for designing the experiments.

Table-3 L_{18} orthogonal array

Exp. No.	Abrasi ve	Feed rate	Speed (RPM)	Ab. Size	Slurry Const.
1	Si C	100	1500	800	15
2	Si C	100	2000	1200	25
3	Si C	100	3000	1000	35
4	Si C	200	1500	800	25
5	Si C	200	2000	1200	35
6	Si C	200	3000	1000	15
7	Si C	300	1500	1200	15
8	Si C	300	2000	1000	25
9	Si C	300	3000	800	35
10	$Al_2 O_3$	100	1500	1000	35
11	$Al_2 O_3$	100	2000	800	15
12	$Al_2 O_3$	100	3000	1200	25
13	$Al_2 O_3$	200	1500	1200	35
14	$Al_2 O_3$	200	2000	1000	15
15	$Al_2 O_3$	200	3000	800	25
16	$Al_2 O_3$	300	1500	1000	25
17	$Al_2 O_3$	300	2000	800	35
18	$Al_2 O_3$	300	3000	1200	15

5. RESULT AND DISCUSSION

Table-4 Observation table

Exp. No.	MRR	S/N Ratio	Ra	S/N
1	1.38	2.813	5.35	-14.57
2	1.33	2.500	4.82	-13.65
3	1.51	3.569	6.23	-15.89
4	1.88	5.468	5.01	-14
5	1.99	5.995	6.55	-16.32
6	1.59	4.038	5.49	-14.79
7	1.97	5.884	5.99	-15.55
8	1.99	5.995	5.67	-15.08
9	2.17	6.729	6.95	-16.84
10	1.61	4.152	6.78	-16.63
11	1.53	3.668	6.19	-15.84
12	1.53	3.668	5.98	-15.54
13	2.17	6.729	7.24	-17.19
14	1.79	5.071	6.54	-16.32
15	1.97	5.884	6.34	-16.04
16	2.05	6.246	8.05	-18.11
17	2.35	7.406	9.04	-19.13
18	2.29	7.186	7.34	-17.31

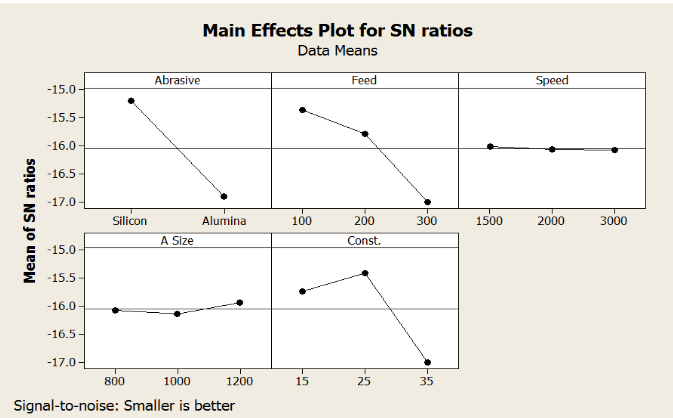

Fig-2 Plot for S/N ratio (Surface roughness)

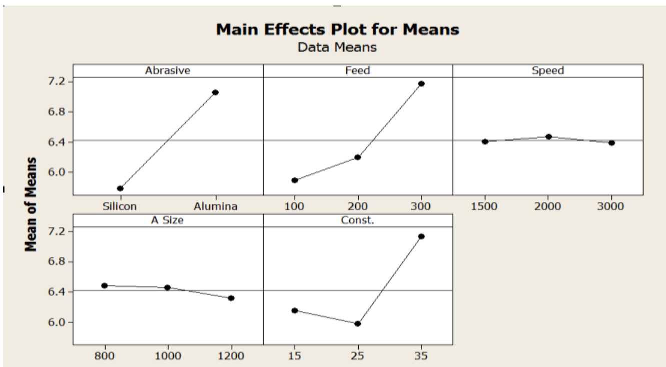

Fig-3 Plot for Mean (Surface roughness)

Feed rate affects the surface roughness the most. Surface finish is better with minimum feed rate. With the increase in feed rate, surface roughness also gets increased. So from three different values for feed rate, it is observed that surface finish is maximum at 100mm/min and minimum when feed rate is 300mm/min. Surface roughness is also affected by speed. It is observed that surface roughness is maximum if speed is 3000rpm & it is minimum at 1500 rpm.

The use of coarser grit size promotes the increase in surface roughness, thus deteriorating the surface quality. Use of coarse abrasive grains result in increase in rate of fractures on the surface thereby increasing the surface roughness. On the other hand use of finer grit size decrease the surface roughness. 1200 grain size provides better surface finish than 1000 & 800 grit sizes. It is also concluded that surface finish is best when slurry concentration is 20% and 25%. Above this value surface became rough.

5.1 Percentage Improvement

It is observed that the lower value of surface roughness is obtained with the silicon abrasive assisted drilling as compared to the drilling with coolant. This can be explained on the basis of low removal rate during the silicon abrasive assisted drilling. As the removal rate is low, very less cavities found on the surface of PMC (E-Glass) during drilling.

Table-5 Comparison of Surface Roughness with abrasive slurry of silicon and drilling with coolant

Exp. No.	Abrasive Assisted Drilling (Ra)(μm)	Drilling With Coolant (Ra)(μm)	% Improvement
1	5.353	5.6	4
2	4.817	6.266	23
3	6.227	7.85	21
4	5.01	6.23	20
5	6.55	7.977	18
6	5.49	8.4	35
7	5.99	7.55	21
8	5.673	8.373	32
9	6.947	8.52	18

% improvement =

$$\frac{\text{Drilling with coolant (Ra)} - \text{Abrasive drilling (Ra)}}{\text{Drilling with coolant (Ra)}} * 100$$

So there is 21.33 % improvement in the surface finish during the silicon abrasive assisted drilling.

Table-5 Comparison of Surface Roughness with abrasive slurry of Aluminum and drilling with coolant

Exp. No.	Abrasive Assisted Drilling (Ra)(µm)	Drilling With Coolant (Ra)(µm)	% Improvement
10	6.783	5.6	-21
11	6.193	6.266	1
12	5.983	7.85	24
13	7.235	6.23	-16
14	6.544	7.977	18
15	6.339	8.4	25
16	8.047	7.55	-7
17	9.044	8.373	-8
18	7.337	8.52	14

There is 3.33 % improvement in the surface finish during the aluminum abrasive assisted drilling

6. ANALYSIS OF VARIANCE (ANOVA)

Table-6 ANOVA for S/N ratio (Surface Roughness)

Source	DOF	SS	MS	F	P	% Contribution
A	1	13.199	13.199	46.11	0	40.05
B	2	8.7976	4.3988	15.37	0.002	26.7
C	2	0.0119	0.0059	0.02	0.98	0.04
D	2	0.1345	0.0672	0.23	0.796	0.41
E	2	8.5217	4.2609	14.88	0.002	25.86
Errors	8	2.2902	0.2863			6.95
Total	17	32.9549				

Table-7 ANOVA for S/N ratio (MRR)

Source	DOF	SS	MS	F	P	% Contribution
A	1	2.7705	2.7705	19.88	0.002	7.01
B	2	31.3805	15.6902	112.58	0	79.4
C	2	0.0355	0.0177	0.13	0.882	0.09
D	2	0.9442	0.4721	3.39	0.086	2.39
E	2	3.2783	1.6392	11.76	0.004	8.29
Errors	8	1.115	0.1394			2.82
Total	17	39.524				

As per this experiment data for surface roughness, type of abrasive is the important factor to consider for surface finish during the abrasive assisted drilling of polymer matrix composite material with a percentage of 40.05% and the feed rate having also significant contribution of 26.70%. Beside this, slurry concentration has 25.86% contribution. The abrasive size having 0.41%, speed having 0.04%.

For MRR feed rate with percentage contribution of 79.40%, Slurry concentration (8.29%), Type of abrasive (7.01) are the significant factors. Abrasive size (2.39%), and speed with (0.09%) are in-significant parameters as their value is below 2.77%.

7. CONCLUSIONS

In case of surface roughness, silicon abrasives of 1200 mesh size with 25 % concentration and a feed rate of 100mm/min with 2000 rpm rotational speed found to be optimized parameters for abrasive assisted drilling.

In case of slurry (silicon) versus drilling with coolant, the average improvement in surface roughness is 21.33 % while for slurry of alumina versus drilling with coolant, the average surface roughness improvement is 3.33%. In case of Material Removal Rate, Aluminum abrasives of 800 mesh size with 35 % concentration and a feed rate of 300mm/min with 2000 rpm rotational speed found to be optimized parameters for abrasive assisted drilling.

In case of Abrasive assisted drilling (slurry silicon) versus drilling with coolant, the average improvement in material removal rate is 2.02 % while for Abrasive assisted drilling (slurry alumina) versus drilling with coolant; the average material removal rate improvement is 10.6%.

Out of all selected parameters, feed rate, type of abrasive and slurry concentration is significantly affecting the surface roughness in abrasive assisted drilling of polymer matrix composite (E-Glass). Rpm and abrasive size gives small effect on surface roughness. Minimum value of Surface roughness is obtained at higher speed and higher abrasive size and at moderate slurry concentration. Material removal is affected by feed rate and type of abrasive. RPM and abrasive size gives mild effect on MRR.

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