Optimization of Drilling Parameters for Hole Quality of Composite Material

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Abstract **- Composites are the materials in which more than one constituents combined microscopically to yield useful properties. These materials contain soft matrix and hard fibers. The machining processes like drilling has effect on mechanical properties of composite materials. In this paper, the optimization of drilling parameters (Cutting speed, Feed rate, Drill point angle)in drilling of CFRP composite specimen is done using Taguchi method, to have maximum value of surface finish of drilled hole.**

Index Terms – drilling, hole quality, Taguchi Method.

I. Introduction

The composite materials are very important due to their ability to replace conventional metals. Composite is a combination of two or more materials that gives different properties than individual one. The main advantages of composite materials are high strength and stiffness. Low density of composite materials allows for low weight of components. Non-isotropic nature of composites creates opportunity to tailor their properties according to design requirements. This flexibility in design allows fiber orientation in the direction of major stresses. Length to diameter ratio of fibers is called *aspect ratio.* Continuous fibers have longer aspect ratios. While using composites in various fields such as aircraft, space, automotive, sporting goods, marine etc. they undergo manufacturing processes. For assembly, drilling of composite parts is necessary. Carbon fiber reinforced plastic (CFRP) materials have wide application areas. The drilling operation causes defects to the CFRP components in the form of delamination, micro-cracks, matrix burning, Fiber pull out etc. [1]. The optimum machining parameters are required for minimum defects to the components in drilling operation.

Due to the damage generated during such machining operations there is change in mechanical behavior of the composite product. R. A. Kishore et al. [1] studied drilling parameters to get maximum after drilling tensile strength using the Taguchi method. The optimum levels of the drill point geometry, the cutting speed and the feed rate have been determined. Drilling is the method which accompanies 40% of all material removal processes. The drilling induced damage could be reduced with the use of special drill bits. C. C. Tsao [2] conducted the drilling experiments with step-core drill to investigate the thrust force. The delamination is related to the thrust force. The parameters taken were diameter ratio, feed rate and spindle speed. Results shows that diameter ratio and feed rate have most significant influence on thrust force. The geometrical parameters of drill have influence on the behavior of drilled composites. The effect of all the forces acting on drill is represented by resisting torque and thrust force. The action at the chisel edge is not truly a cutting action, but it is pushing action into material like a wedge. The optimization of drilling parameters like cutting speed, feed, point angle and chisel edge width in drilling of glass fiber reinforced polymer (GFRP) composites is done by Vinod Kumar Vankanti et al. [3]. The aspects of the mathematical analysis and use of non traditional methods in machining of composites is reviewed by H. Hocheng et al. [4]. Among the various drill types twist drill causes larger thrust force, but still it is most economic to use twist drills. As drilling induced thrust force increases beyond critical thrust force the delamination occurs. The evaluation of delamination factor in drilling of CFRP composites is done by C. C. Tsao et. al. with the use ultrasonic C-scan technique [5]. The technique of acoustic emission for measurement of residual tensile strength of drilled composite was used by Navid Zarif Karimi et al. [6]. Acoustic emission means the generation of transient elastic waves by the rapid release of energy from localized sources within a material which is under deformation. This is most accurate method for determining mechanical properties of composite materials.

II. Experimentation

A. CFRP specimen and Cutting tool

The specimen is prepared with bi-directional fabric of carbon fiber by hand lay up using compression moulding process. The fiber orientation was kept at 0° and 90°. Phenolic resin bonding material was used. The specimen geometry was taken as per ASTM D3039 standards. For drilling process HSS twist drills of 8mm diameters were used. The parameters and their levels were decided looking at their significance from literature.

B. Experimental set up

The drilling was done on fully automatic vertical milling machine of BFW make and BMV-40 model. The power rating of spindle motor is 3.7 KW and spindle speed range of 60-6000 rpm. The machine has cutting feed rate range of 1-4000 mm/min. The geometry of specimen for drilling as per ASTM D3039 is shown in fig.1. For drilling four parameters having three levels each were used. The process parameters taken were cutting speed and feed rate. Drill point angle and chisel edge width were the geometrical parameters. The cutting speed was varied from 1500 to 2500 rpm while feed rate values taken were 10, 15 and 20 mm/min. The drilling process on vertical milling machine is shown in fig. 2.

III. TAGUCHI METHOD

A full factorial design results in large number of experiments. This full factorial design considers all the possible combinations of factors and levels for the experiments. It is not practically possible every time to conduct experiments for all possible combinations. So, in Taguchi method small set from all possible combinations is taken and it is called as partial fraction experiment. Also Taguchi analysis provides special set of general design guidelines for factorial experiments [1]. Taguchi method gives following steps for designing the experiments[1]: (1) establishment of objective function (2) identification of factors and their levels (3) selection of appropriate orthogonal array (4) experimentation (5) analysis of data and determination of optimal levels (6) the confirmation experimentation.

A. Establishment of objective function

The objective of Taguchi method is to produce high quality product in minimum cost to the manufacturer. The main objective of this study is to determine optimal parameter levels which will give maximum surface finish of drilled hole. The drilling is done in carbon fiber composite.

B. Identification of factors and their levels

In Taguchi method the factors affecting the quality of process are divided as control factors and noise factors. Control factors are set by manufacturer and can be adjusted. The noise factors are due to uncontrollable factors and these causes variation in output. Control factors are most important for quality of product characteristic. In present study, the process parameters taken were cutting speed (rpm) and feed rate (mm/min). The geometrical parameters were drill point angle (degree) and chisel edge width (mm). These parameters with three levels each were taken. The parameters and their levels are shown Table I.

TABLE I
FACTORS AND LEVELS FOR EXPERIMENT

		Factors			
		A:Speed (rpm)	B: Feed (mm/min.)	C:Drill point angle(deg.)	D: Chisel edge width(mm)
Levels	1	1500	10	100	1
	2	2000	15	118	2
	3	2500	20	135	3

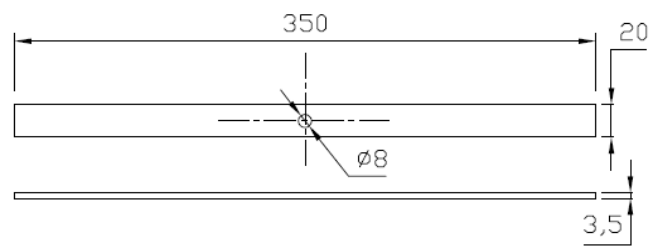

Fig. 1 Specimen Geometry (As per ASTM D3039, All dimensions are in mm)

C. Selection of Taguchi orthogonal array

The Taguchi orthogonal array gives minimum number of experiments which could give full information of all the factors that affect the performance. There are many standard orthogonal arrays are available. In each array there are specific number of independent design parameters and levels. The L_9 orthogonal array is used in this study. Table II shows L_9 orthogonal array.

IV. MEASUREMENT AND ANALYSIS

The surface roughness of drilled hole is measured by surface tester of make Mitutoyo and SJ-400 model. Among Ra, Rz and Rq values obtained from surface tester, the Ra value is considered for deciding hole quality. As drilling on experiments 2, 3, 5 and 9 were done the Ra values for these four experiments were measured. For each specimen three trial readings were taken. The experimental results of the L_9 orthogonal array experiment are shown in Table III.

TABLE II
TAGUCHI L_9 ORTHOGONAL ARRAY

Experiment No.	Speed (rpm)	Feed (mm/min)	Drill point angle (degrees)	Chisel edge width (mm)
1	1500	10	100	1
2	**1500**	**15**	**118**	**2**
3	**1500**	**20**	**135**	**3**
4	2000	10	118	3
5	**2000**	**15**	**135**	**1**
6	2000	20	100	2
7	2500	10	135	2
8	2500	15	100	3
9	**2500**	**20**	**118**	**1**

Fig. 2 Drilling process on vertical milling machine

TABLE III
EXPERIMENTAL RESULTS OF THE L_9 ORTHOGONAL ARRAY EXPERIMENT

Experiment No.	Surface roughness Ra value (μm)			Average value Ra
	Trial I	Trial II	Trial III	
2	1.42	1.49	1.38	1.43
3	1.04	1	1.19	1.07
5	1.17	1.18	1.23	1.19
9	2.71	2.69	2.63	2.68

V. CONCLUSION

The tests for four experiments taken for which results are as shown in Table III. It has seen from results that surface roughness value is minimum for experiment number 3. The arithmetic average roughness (Ra) value is taken in to consideration for hole quality. The minimum obtained value of Ra is 1.07μm. The cutting speed, feed rate, drill point angle and chisel edge width values for minimum Ra are 1500 rpm, 20 mm/min., 135 degree and 3 mm respecively. The actual optimum factors with their levels for minimum surface roughness of drilled composite will be obtained when tests for all nine experiments will be carried out.

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