Proceedings of the
International Conference on Mechanical Engineering 2003
(ICME2003) 26-28 December 2003, Dhaka, Bangladesh

ICME03-AM-47

SOME STUDIES ON THE DRILLING OF GFRP COMPOSITE MATERIALS WITH HSS TOOL

D. G. Thakur[1], P. K. Brahmankar[1], M Sadaiah[1] and Patel Sujan[2]

[1]Department of Mechanical Engineering,
Dr. Babasaheb Ambedkar Technological University,
Lonere-402 103, Raigad, Maharashtra-INDIA
E-mail: dineshsingh_thakur@yahoo.com
[2]Department of Industry and Technology,
Millersville University, PA
USA

ABSTRACT

In the recent years, the reinforced plastics are extensively used in many engineering applications as a substitution for the conventional materials. With an increase demand for composite materials like glass fiber reinforced Plastic (GFRP), carbon fiber reinforced plastic (CFRP) and others, the need to drill such products are increasing rapidly. In the present work drilling tests were carried out on GFRP composites with conventional HSS drill bit and then by modifying the drill geometry i.e. grooved cutting edge in order to show the effect of drill geometry on the performance of the drilling of GFRP composite. It is observed that the fiber orientations and drill geometry plays a vital role on the cut quality and delamination. This paper reports the findings in that direction.

Keywords: Delamination, GFRP, Tool wear, HSS, etc.

1. INTRODUCTION

The word composite means consisting of two or more distinct parts. Composite materials are widely used in the diverse applications such as aircraft, automobile, sporting goods, marine vessels, audio equipment etc. Because of it's unique properties such as specific strength, fatigue strength, strength to weight ratio and corrosion resistance.

Machining of composite in general and Glass Reinforced plastics (GFRP) in particular differ in many respects from metal cutting. The material is inhomogeneous and its machining behavior depends on fiber, matrix properties, fiber orientation and type of weave. So also based on the fiber content and orientation the properties of the composite vary. Most composite structures are fabricated to near net shape. Drilled holes are often required to assemble the near net-shaped structures or parts. Thus drilling is the most common cutting operations carried out on FRP. In spite of near-net shape manufacturing, machining of FRP products to some extent becomes usually necessary so as to achieve the shape and dimensional tolerance to facilitate assembly and also for the control of surface quality from functional viewpoint [6,8]. The most common machining operation for GFRP parts is drilling [6-8]. It is observed that delamination, fibre pullout, severe tool wear, damage to the surface finish and slow speeds are some of the major problems associated with the drilling operation. Laminated fiber-reinforced plys under machining forces are subject to the risk of interlaminar crack propagation, called delamination, which threatens structural reliability. Such damage results in a new limiting factor to the machinability of composite materials. From literature survey it is found that the above problems are likely to develop as a result of the fiber orientations, feed rate and tool geometry, especially cutting edge of the drill [1-7].

They can be eliminated by using specially designed carbide tools, poly-crystalline diamond (PCD) tools, solid carbide tools etc. But these tools are very costly and not compatible with the existing machine tools. Therefore, in the present work High Speed Steel (HSS) 18-4-1 drill bit of 6mm diameter is used on the basis of availability, facility to maintain a sharp edge, toughness and easy grindability.

Some investigators have studied the delamination experimentally. A rapid feed rate of drilling will cause a crack around the exit edge of the hole. Other scientist postulated that lower axial thrust will create less delamination. Koenig et al. ran a series of drilling tests on carbon reinforced epoxy and measured the critical thrust force at the one set of exit delamination. Ho-cheng and Dharan developed the push out and pull out models at exit and entrance, respectively, using linear elastic fracture mechanics and classic plate bending theory for prediction of the critical thrust force at one set of delamination [4].

2. EXPERIMENTAL DETAILS

The drilling experiments were carried out on a robust CNC machine with the following specifications:
Make: TRIAC make CNC Milling Machine
Table size: 500 x 160 x 280 mm,
Axes Travel X, Y and Z: 250 mm, 120 mm and 235 mm respectively.
Spindle Speed and Spindle Drive: Infinitely Variable and ½ HP, 240 AC res.
Axis Drive: X, Y, & Z axes (stepper motors-200 steps/rev).
Feed Rates: Infinitely Variable (0-1000 mm/min)
Linear Interpolation: On X, Y, and Z axes (vertically corrected feed rates).
Circular Interpolation: On XY plane.

3. SELECTION OF THE WORK MATERIAL

Woven glass fibre fabric was chosen as the work material. This material was cut into 350x350 mm pieces with 0°, 45°, 90° for laying the laminates. The workpieces were made by hand lay-up method with of 35% volume fraction of the glass fibres. Epoxy with 27% hardener was used as matrix. The laminates were hot cured in a furnace at a temperature of about 110°C for five hours. The laminates were laid at (0±0), (0±45), (0±90), and (0, 45, 90) degrees.

4. SELECTION OF CUTTING TOOL

ϕ6 mm high speed steel (HSS) cutting tool was selected for cutting the unidirectional (UD) laminates. HSS was selected since it is cheap, easily grindable, highly tough and compatible with the above machine.

5. CHARACTERIZATION OF WORKPIECES

All the workpieces, i.e. (0±0), (0±45), (0±90), and (0, 45, 90) degrees were characterized for tensile strength, shear strength and flexural strength. Test pieces of following dimensions were used for this purpose: (300x25) mm for tensile test, (200x20) mm for shear test and (80x10) mm for the flexural test. All these dimensions are based on ASTM standards. The results of these tests are presented in Table 1.

Table 1 Characterisation of Workpieces

Fiber orient^n	Tensile Strength (MPa)	Shear Strength (MPa)	Flexural Strength (MPa)
(0±0)	4512	110.4	159.7
	4213	84.9	153.8
	4712	78.6	161.6
(0±45)	760	423	57.3
	920	363	58.9
	818	397	50.6
(0±90)	2600	75	18.4
	2740	69	14.2
	2680	74	11.4
(0,45,90)	1750	215	38.5
	1650	270	44.6
	1762	212	37.6

6. SELECTION OF PERFORMANCE MEASURES

The previous work [1-7] on drilling of FRPs has shown that the quality of drilled hole depends on the thrust and torque acting on the drill and also the wear of the drill (tool wear). Hence, it was decided to choose all these parameters as the performance measures in this study as well. A drilling dynamometer was used for the measurement of thrust and torque. A Toolmaker Microscope with a least count of 0.01mm was used to measure the tool wear.

7. EXPERIMENTAL PROCEDURE

The experiments were conducted on the above-mentioned CNC machine with a ϕ6 mm HSS drill bit. The experimental set up is a shown in figure 1. All the workpieces were drilled for 50,100,150 and 200 holes with following optimum operating speeds and feeds (Table 2) with a normal geometry drill bit and modified geometry i.e. grooved cutting edge modification. After each interval of 50 holes, thrust, torque and tool wear i.e. flank wear, were measured.

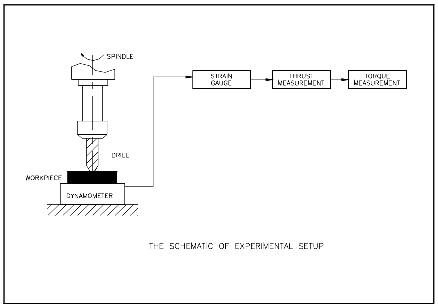

Figure 1 Experimental set-up

Table 2 Optimal Operating Parameters

Work piece type	Speed (Rpm)	Feed (mm/rev)
(0 ± 0^0)	1700	0.16
(0 ± 45^0)	2500	0.10
(0 ± 90^0)	2500	0.16
$(0,45,90)^0$	1000	0.16

After drilling every 50 holes with the above operating parameters measurements were taken for thrust, torque and tool wear. The variation of these performance measures with respect to number of holes were plotted.

8. RESULTS AND DISCUSSION

Drilling is a complex 3D cutting operation with the cutting conditions varying along the entire cutting edge from the axis to periphery. Drills specially small drills are characterized by relatively high thrust force due to large web thickness predominant negative rake and low cutting speed at the cutting edge, which again is quite sizable compared to the drill size in case of small drills.

Vibration and rapid wear lead to inaccuracy, poor surface finish and reduced tool life.
The workpieces were characterised as per the ASTM standards and presented in the form of table to highlight the effect of fiber orientations.
Here GFRP laminates of different fiber orientations were drilled with normal geometry and modified cutting edge drill geometry as shown in figure 2. Modification of cutting edge was done on the Electrical discharge machine (EDM). Because of grooved cutting edge we got powdery chips which is quit common while machining GFRP. The material is cut by the long curved cutting edge and this results in segmental chips of powdery form.

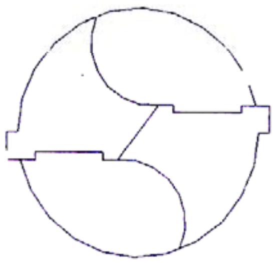

Figure 2 Modified cutting edge

Figure 3 and 4 shows the variation of thrust, torque and tool wear with different feed for different fiber orientation, with normal geometry and modified drill geometry i.e. grooved cutting edge.

It was clear from the series of the experimental results obtained in both the series of drilling tests that the effect of the cutting edge shapes on the thrust, torque and tool wear tend to be the same as the effect of the grooved cutting edge on the fiber orientations. Thus the smaller the cutting force, lesser will be the delamination. It is therefore necessary to reduce the thrust and torque in drilling GFRP composite in order to improve still more the cutting performance of drills with the cutting edge.
Based on these experiments, it became clear that the fiber orientations and drill geometry (cutting edge) are the major contributors to the thrust force and hence the occurrence of delamination in laminated composite.

9. CONCLUSION

The following conclusions can be made after characterizing and drilling GFRP composite materials with normal drill point geometry and modified (grooved cutting edge) geometry:
The mechanical properties of the GFRP composites are found to strongly depend on the orientation of the fibres. While the (0±0) orientation is superior in tensile strength because the load applied is in the direction of the fibre axis, (0±45°) orientation is shows higher shear strength. An optimum fibre orientation, i.e. (0,45,90), is found to show moderate properties in tension as well as shear.
It is found from the experiments that the drill geometry plays a prominent role in reducing the thrust which in turn reduces the delamination of GFRP composite. As seen from the figures grooved cutting edge geometry of HSS drill reduces the thrust force , torque and tool wear for all four fiber orientations by around 25-30% compared to normal drill point geometry. This highlights the need to modify tool geometry to obtain the subcritical thrust at a reasonable feed rate. Hence the type of damages induced in a GFRP composite material during drilling is strongly dependent on fiber orientations and the drill point geometry.

10. REFERENCES

1. Armarego E J A, Wright, J D, 1984, ‘Predictive models for drilling thrust and torque-a comparison of three flank configurations’ Annals of CIRP V33/1/1984, p 41-45.
2. Bhattacharyya A, Chattopadhyay, A B and Roy R, 1981, ‘Chisel-edge modification of small HSS and carbide drills for improved machinability’ Annals of the CIRP, V30/1/1981, p21-25.
3. Caprino G, and Diterlizzi, A, 1995, ‘Damage development in drilling GFRP’ I. J. Mach. Tools Manuf. V35, 1995, p817-829.
4. Chang H W, 1983, ‘Wear characteristics of composites: effect of fiber orientation’ Wear, V85, 1983, p81-91.
5. Eliezer Z, Khanna V D, and Amateau, M F, 1979, ‘On the effect of fiber orientation on the wear of composites materials’ Wear, V53, 1979, p387-389.
6. Everstine G C and Rogers, 1971, ‘A theory of machining of reinforced materials’ J. Composites Materials, V5, 1971, p94-106.
7. Gindy N N Z, 1988, ‘Selection of drilling conditions for glass fiber reinforced plastics’ Int. J. Prod. Res. V26(8) 1988, p1317-1327.
8. Hocheng h and Puw H Y, ‘On drilling characteristics of fiber reinforced themoset and thermoplastics’ I. J. Mach. Tools Manuf. V32, p583-592.
9. Knibbs R H and Morris J B, 1974, ‘The effects fiber orientation on the physical properties of composites’ Composites, 1974, p209-218.
10. Koning W, Wulf Ch., Grab P, 1989, ‘Quality definition and assessment in drilling of fiber reinforced thermosets’ Annals of the CIRP V38/1/1989, P119-124.
11. Koning W, Wulf Ch., Grab P, Willerscheid, 1985, ‘Machining of fiber reinforced plastics’ Annals of CIRP, V34/2/1985, p537-548.
12. Koning W, Grass P, Heintze A, Okcu F, and Schmitz-justin C, 1984, ‘Developments in drilling and countouring composites containing Keveler’ Prod. Eng. 63(8), 1984, p56-61.