International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 15
May 2018

Experimental Investigation to Optimize Process Parameters in Drilling Operation for Composite Materials

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ABSTRACT

This paper discusses the influence of cutting parameters in drilling of carbon fiber reinforced composites. The experiments are conducted to study the effect of point angle, spindle speed and feed rate on cutting force using HSS twist drills. This paper presents a mathematical model for correlating the interactions of drilling parameters and their effects on cutting forces. The optimum value of cutting parameters is also determined to get minimum value of cutting forces. Diameter of drilling cutting tool is 12mm, 8mm. theoretical calculations are done to calculate thrust force and torque. The assembly of work piece and tool are modeled in Pro/Engineer. The input parameters considered are point angle 118^0 and 120^0, tool diameter, spindle speed, feed rate and materials. Different combinations of the above parameters are considered to get the minimum value of cutting forces. Structural analysis is done on the assembly to verify the stresses for different materials Mild Steel, Aluminum alloy and carbon fiber reinforced composites.

INTRODUCTION TO DRILLING

Drilling is the operation of producing a cylindrical hole by removing metal by the rotating edge of a cutting tool called the drill. The drilling is one of the simplest methods of producing a hole. Before drilling the centre of the hole is located on the work piece by drawing two lines at right angles to each other and then a centre punch is used to produce an indentation at the centre. The drill point is pressed at this centre point to produce the required hole. Drilling does not produce an accurate hole in a work piece and the hole so generated by drilling becomes rough and the hole is always slightly oversize than the drill used due to the vibration of the spindle and the drill. A 12 mm drill may produce a hole as much as 0.125 mm oversize and a 22 mm drill may produce one as much as 0.5 mm oversize.

MATERIALS

Many different materials are used for or on drill bits, depending on the required application. Many hard materials, such as carbides, are much more brittle than steel, and are far more subject to breaking, particularly if the drill is not held at a very constant angle to the work piece, e.g. when hand-held

LITERATURE SURVEY

The paper by J.Pradeep Kumar, P.Packiaraj [1], utilized taguchi method to investigate the effects of drilling parameters such as cutting speed (5, 6.5, 8 m/min), feed (0.15, 0.20, 0.25mm/rev) and drill tool diameter (10, 12, 15mm) 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 using DECKEL MAHO-DMC 835V machining center. In the paper by **Yogendra Tyagi, Vedansh Chaturvedi, Jyoti Vimal[2],** the drilling of mild steel with the help of CNC drilling machine operation with Tool use high speed steel by applying Taguchi methodology has been reported. The Taguchi method is applied to formula 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.

EXPERIMENTAL WORK

Drilling operations are performed on the carbon fibre reinforced composite. The original carbon fibre comes in the form of cloth which is reinforced with Epoxy Resin with number of layers. The carbon fibre is reinforced with epoxy resin with 11layers with total thickness of 3mm of 2 pieces each. 100gms of epoxy resin with 12 to 18% hardner is mixed and applied between each layer of carbon fibre. The final carbon fibre reinforced composite is as shown in figure below.

Drilling operations are performed on these pieces with the given parameters.

Fig – Carbon Fiber piece

e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 05 Issue 15
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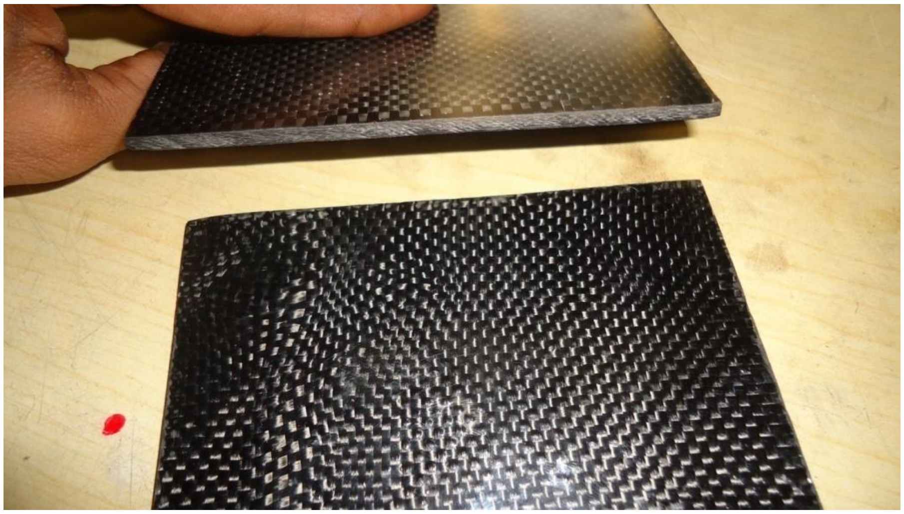

Fig – Two samples of Carbon Fiber

Drilling is performed on a CNC Vertical Milling Machine.

Machine Specifications

Chenho manufacturer, Meldas Controller.
Its specification is X – 1820mm, Y – 850mm, Z – 790mm.

The following parameters are taken for experimentation

Tool Material – HSS
Tool Diameters – 8mm and 12mm
Point Angles – 118^0 and 120^0
Speed – 1000rpm and 2500rpm
Feed – 0.2 mm/min (8mm dia) and 0.35mm/min (12mm dia)

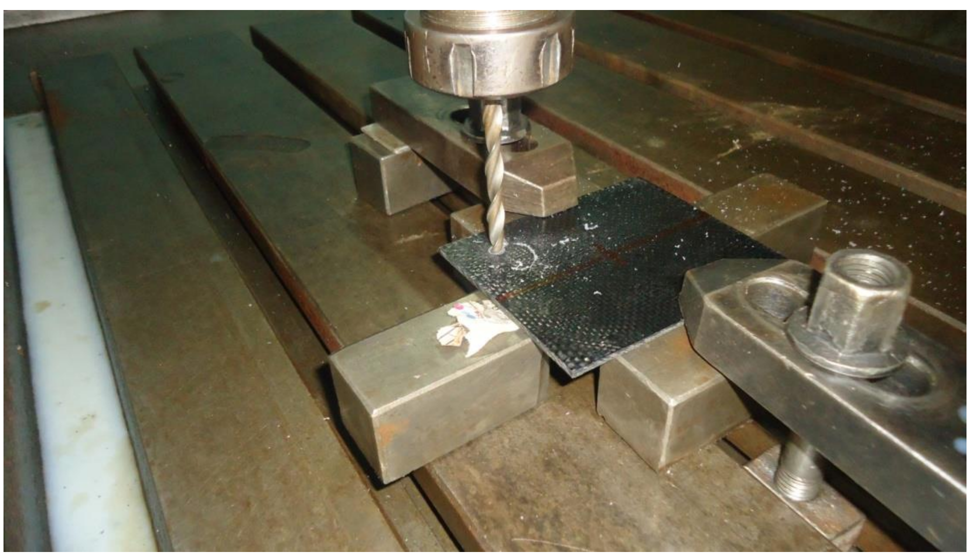

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Fig – Drilling operation on Carbon Fiber

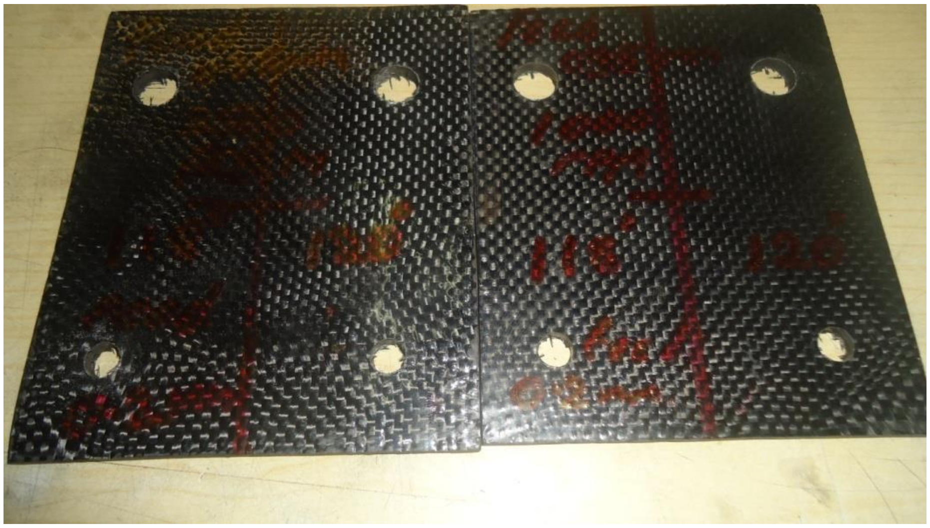


Fig – Final pieces after drilling

The cutting forces are measured using Drill Tool Dynamometer. The Sensing Unit consists of a cylinder with strain gauges cemented on it. The unit accurately senses the Axial Thrust up to 200 Kg and Radial Force (Torque) up to 10Kg. independently and feed the output to the Bridge Balance Unit.

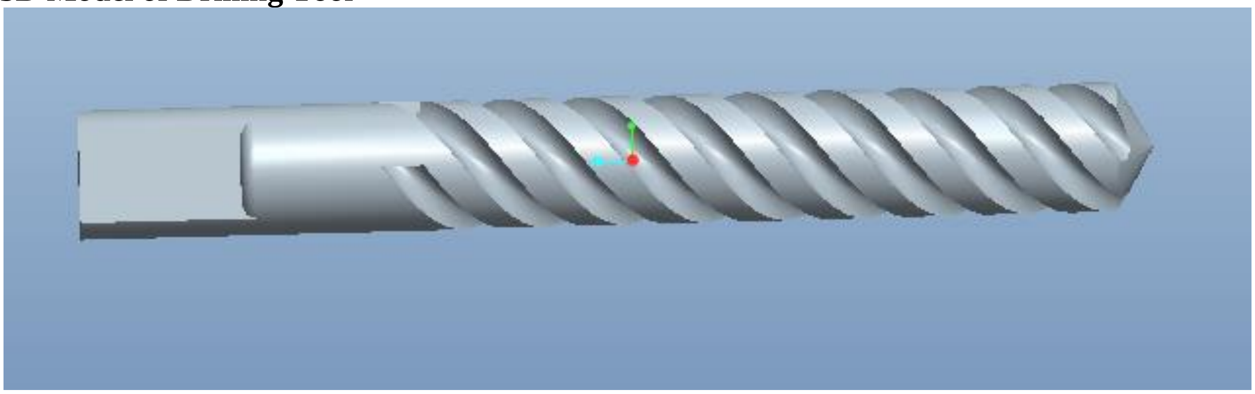
This equipment includes power supply unit, which supplies a stabilised D. C. Power to the two bridge circuits. A separate bridge balancing and power supply unit is essential for each dynamometer.

The values of cutting forces and material removal rates are measured while drilling and the results are as tabulated below:

Table – Cutting forces and MRR Results

TOOL DIA (mm)	POINT ANGLE (deg)	SPEED (rpm)	FORCE (N)	MRR (mm^3/sec)
8	**118**	**1000**	524.7	10.67
		2500	671.3	20.57
	120	**1000**	586.1	12.55
		2500	714.8	25.41
12	**118**	**1000**	795.5	28.96
		2500	905.4	33.2
	120	**1000**	843.2	31.1
		2500	987.7	49.98

3D Model of Drilling Tool



THEORETICAL CALCULATIONS

Cutter speed

$$V_c = \frac{D\pi n}{1000} \text{ m/min}$$

Feed per revolution

$$f = f_z \times z$$

Feed rate

$$V_f = f \times n$$

Material Removal Rate

$$Q = \frac{Vf \times \pi \times Dc^2}{4 \times 1000} \text{ cm}^3\text{/min}$$

Torque $= \frac{Pc \times 9500}{n}$ (or)

$$= \frac{Dc^2 \times Kc \times f}{8000}$$

Cutting Force

$$F = \frac{K' \times Kc \times f \times d}{2}$$

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K^1=co-efficient of k^1 depends on the geometry of the tip of tool

{we can consider an average value 0.5}

STATIC STRUCTURAL ANALYSIS

8mm DIAMETER – 118^0 Angle

CARBON FIBER

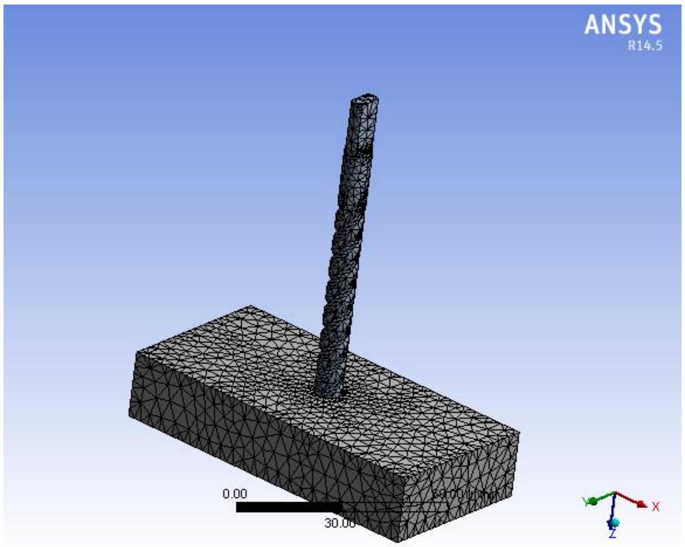

Fig – Meshed Model of assembly of tool and work piece

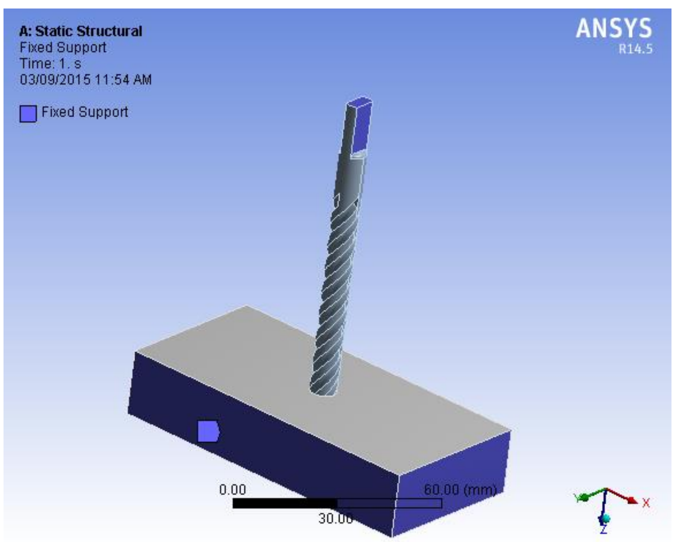

Fig – Fixed support applied on the work piece and on top of cutting tool

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p-ISSN: 2348-795X
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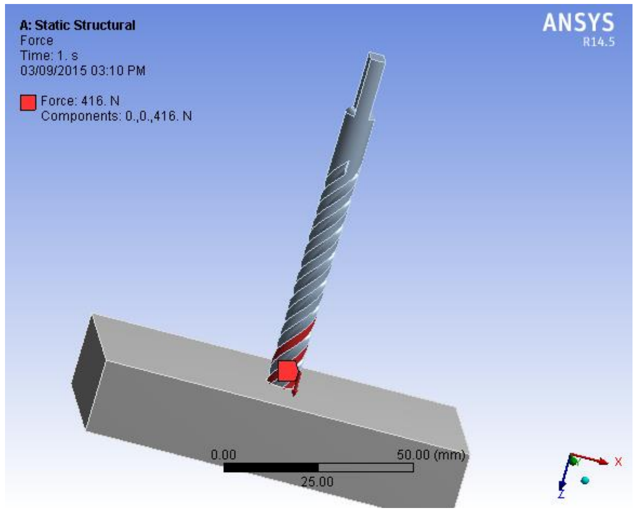

Fig – Force applied on drills

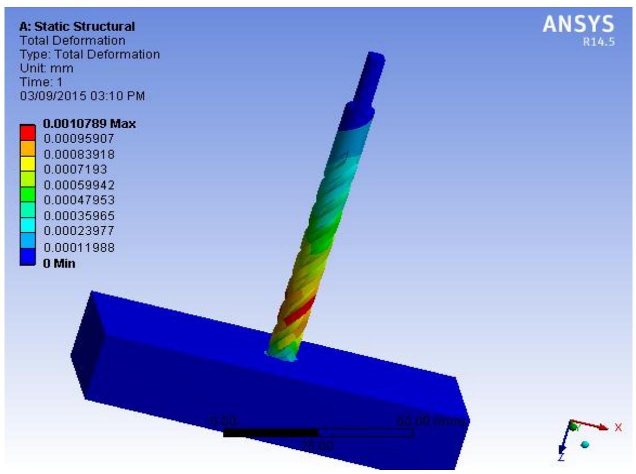

Fig – Deformation using Carbon Fiber

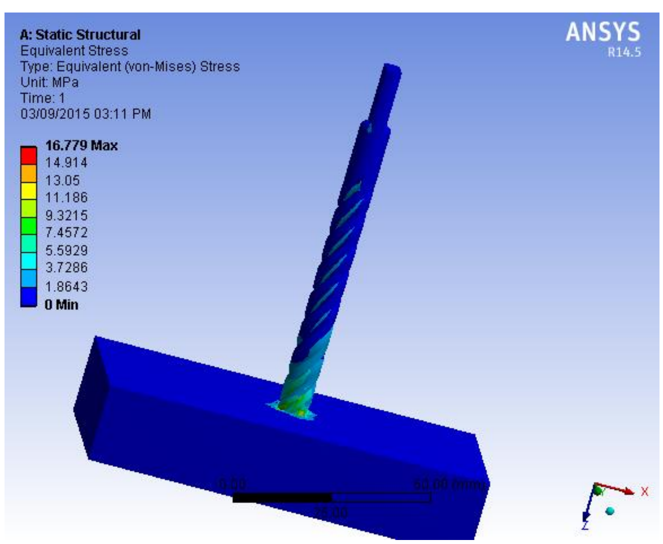

Fig – Stress using Carbon Fiber

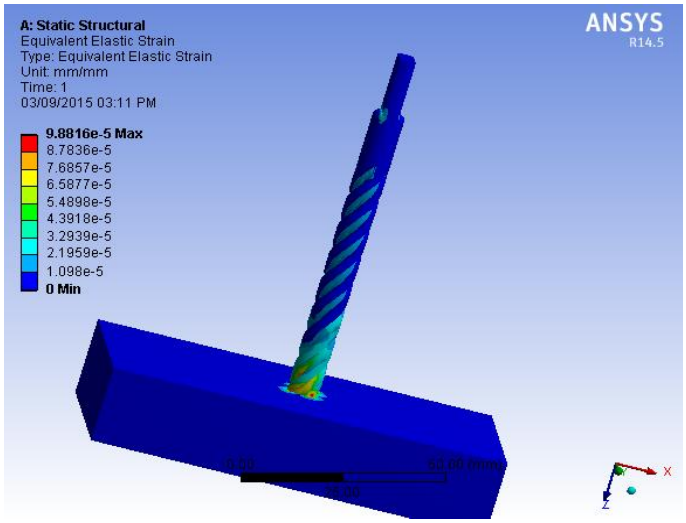

Fig – Strain using Carbon Fiber

RESULTS TABLE

8 mm DIA

ANGLE	MATERIAL	DEFORMATION (mm)	STRESS (N/mm^2)	STRAIN
118	ALUMINIUM	0.0031891	29.11	0.00033015
	MILD STEEL	0.0038284	72.919	0.00039144
	CARBON FIBER	0.0010789	16.779	9.8816E-5
120	ALUMINIUM	0.0011885	34.75	0.00016549
	MILD STEEL	0.0039617	115.83	0.00055164
	CARBON FIBER	0.0011194	24.239	0.00016161

12 mm DIA

ANGLE	MATERIAL	DEFORMATION (mm)	STRESS (N/mm^2)	STRAIN
118	ALUMINIUM	0.0020823	26.9	0.00042547
	MILD STEEL	0.0026678	84.764	0.00043715
	CARBON FIBER	0.00073645	18.377	0.00013389
120	ALUMINIUM	0.0020521	26.182	0.00041068
	MILD STEEL	0.0026289	81.305	0.00041489
	CARBON FIBER	0.00072544	17.759	0.00012782

CONCLUSION

Material removal rates and forces are determined by varying the above parameters. By observing the experimental results, the forces and material removal rates are increasing by increasing the point angle and spindle speed. So to achieve higher material removal rates the better parameters are, spindle speed – 2500rpm, feed –

e-ISSN: 2348-6848
p-ISSN: 2348-795X
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0.35mm/rev, and point angle – 120^0 and to reduce forces the better parameters are, spindle speed – 1000rpm, and point angle – 118^0. Forces are calculated using theoretical calculations. 3D modeling is done in Pro/Engineer and analysis is done in Ansys. Analysis is performed and the stresses, displacements are compared for three materials Mild Steel, Aluminum and Carbon Fiber. By observing the analysis results, the stresses and displacements are less for Carbon Fiber than Mild Steel and Aluminum.

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