International Journal of Engineering Research and Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 12, Issue 10 (October 2016), PP.49-62

Optimizing Process Parameters in Drilling of Aramid Fiber Composite Material

V.V.R.L.S. Gangadhar[1]Kiran Reddy Janagam[2]B.Anil Kumar[3]
[1]*Professor, DeptOf Mech Engineering,Princeton College OfEngineering, Hyderabad, India*
[2]*Dept Of Mech Engineering, Princeton College OfEngineering, Hyderabad, India*
[3]*Asst.Professor, DeptOf Mech EngineeringPrinceton College OfEngineering, Hyderabad, India*

Abstract: In the present investigation experiments were conducted to study the effect of point angle, spindle speed and feed rate on Material removal rates and time taken to drill on Aramid Fiber composite. The input parameters considered and used are point angle 118^0 and 120^0, tool diameter 10.2mm and 6.5mm, spindle speeds 1500rpm, 2000rpm & 2500rpm, feed rate 30mm/min. Different combinations of the above parameters are considered to get the maximum value of MRR. Theoretical calculations are done to calculate thrust force and torque. The assembly of work piece and tool are modeled in Pro/Engineer. Structural analysis is done on the assembly in Ansys to verify the stresses for different materials Mild Steel, Aluminum alloy and Aramid Fiber composites. Taguchi method from Minitab software is used to optimize speed and angle for both diameters for time taken for drilling.

Keywords: Optimization of Speed and Angle for Better Material Removal Rate, StructuralAnalysis, Taguchi Method, Aramid fiber, Ansys Software.

I. Introduction

Drilling is a cutting process that uses a drill bit to cut or enlarge a hole of circular cross-section in solid materials. The drill bit is a rotary cutting, often multipoint. The bit is pressed against the workpiece and rotated at rates from hundreds to thousands of revolutions per minute. This forces the cutting edge against the work piece, cutting off chips from the hole as it is drilled. A drill is a tool fitted with a cutting tool attachment or driving tool attachment, usually a drill bit or driver bit, used for boring holes in various materials or fastening various materials together with the use of fasteners. Drills are commonly used in woodworking, metalworking, construction and do-it-yourself projects. Specially designed drills are also used in medicine, space missions and other applications. Drills are available with a wide variety of performance characteristics, such as power and capacity.

A. Introduction to Taguchi Method

Dr. Taguchi of Nippon Telephones and Telegraph Company, Japan has developed a method based on “ORTHOGONAL ARRAY” experiments which gives much reduced “variance” for the experiment with "optimum settings" of control parameters. Thus the marriage of Design of Experiments with optimization of control parameters to obtain best results is achieved in the Taguchi Method. "Orthogonal Arrays" (OA) provide a set of well balanced (minimum) experiments and Dr. Taguchi's Signal:to: Noise ratios (S/N), which are log functions of desired output, serve as objective functions for optimization, help in data analysis and prediction of optimum results.

B. 8 Steps in Taguchi Methodology

Taguchi method is a scientifically disciplined mechanism for evaluating and implementing improvements in products, processes, materials, equipment, and facilities. These improvements are aimed at improving the desired characteristics and simultaneously reducing the number of defects by studying the key variables controlling the process and optimizing the procedures or design to yield the best results.
Taguchi proposed a standard 8 step procedure for applying his method for optimizing any process.
Step 1: Identify the main function, side effects, and failure mode
Step 2: Identify the noise factors, testing conditions, and quality characteristics
Step 3: Identify the objective function to be optimized
Step 4: Identify the control factors and their levels
Step 5: Select the orthogonal array matrix experiment
Step 6: Conduct the matrix experiment
Step 7: Analyze the data, predict the optimum levels and performance
Step 8: Perform the verification experiment and plan the future action.

II. Literature Review

In the paper by BIREN DESAI [1],the Focus of his experimental study is to optimize the cutting parameters through work piece circularity and Hole size. This paper reports an experimental investigation of a full factorial design performed on thin CFRP Laminates using coated Solid carbide drill with point angle 600 and helix angle 300 by varying the drilling Parameters such as spindle speeds (1500, 2500, 3500, 4500 and 6000 rpm) and feed rate (0.01, 0.03, 0.07, 0.1 And 0.15 mm/rev) to determine optimum cutting conditions. The hole quality parameters analysed include hole Diameter and circularity. Analysis of variance (ANOVA) was carried out for hole quality parameters and their Contribution rates was determined. Design of Experiments (DOE) methodology by full factorial Design was Used in the multiple objective optimizations (using Mini Tab 15, software) to find the optimum cutting conditions for defect free drilling.

The paper by R.M. Kulkarni [3],focused on investigating the effects of drilling parameters like spindle speed (600rpm, 16.560 rpm and 2700 rpm), Feed rate (0.1mm/rev, 0.2mm/rev and 0.3mm/rev), drill point angle (116.50, 1100 and 900), drill material (HSS, Co-HSS and Tungsten Carbide) and carbon black (0, 4 and 6.5 wt. %) on the responses: thrust force and delamination factor (entry and exit) in drilling of carbon black dispersed vinyl ester GFRP, by Design of Experiments approach. Drilling experiments were designed to control the drilling parameters based on L27Orthogonal Array. The experimental results were analysed using MINITAB V16. Signal-to-Noise (S/N) ratio, ANOVA and Grey Relation Analysis (GRA) were employed to analyse the effect of drilling parameters on the quality of the drilled holes. Minimum value of thrust force was obtained for 4 wt% carbon black, 2700 rpm, 0.1 mm/rev, 1100 drill point angle and HSS drill. Delamination was minimum for 4 wt% carbon black, 2700rpm, 0.1mm/rev, 4mm diameter with Tungsten Carbide (WC) drill. SEM confirmed that delamination at the exit is greater than delamination at the entry.

The paper by J Babu, Tom Sunny [4],presents delamination study of composite materials by conducting drilling experiments using Taguchi's L25, 5-level orthogonal array and Analysis of variance (ANOVA) was used to analyse the data obtained from the experiments and finally determine the optimal drilling parameters in drilling GFRP composite materials. Experiments were also conducted to determine whether varying feed & spindle speed during drilling could reduce the delamination.

III. Experimental Investigation

In this thesis, drilling operations are conducted on the Aramid Fiber pieces with 6.5mm and 10.2mm diameter drills with 118^0 and 120^0 point angles for depth of cut 3mm with different cutting parameters.

The cutting parameters are spindle speed – 1500rpm, 2000rpm and 2500rpm, Feed Rate – 0.3mm/rev and NC program is generated manually and program is fed to machine by using CIMCO edit file.

C. *Experimentation Photos:*

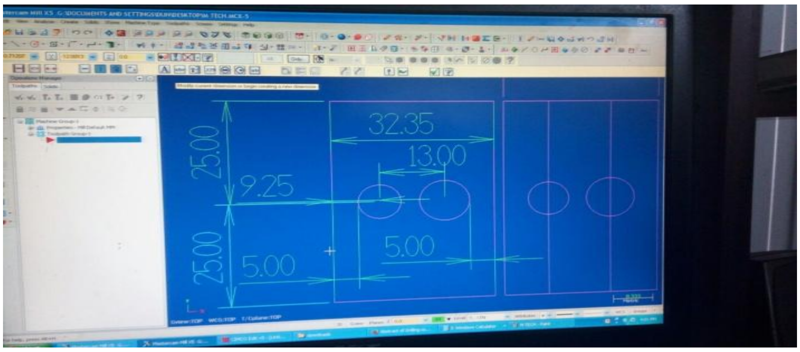
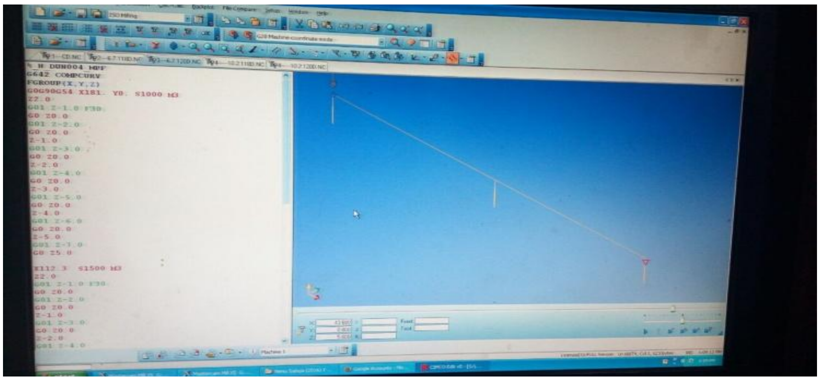


Fig.1:2D drawing for drilling



```
%_N_DUN004_MPF
G642 COMPCURV
FGROUP(X,Y,Z)
G0G90G54 X181. Y0. S1000 M3
Z2.0
G01 Z-1.0 F30.
G0 Z0.0
G01 Z-2.0
G0 Z0.0
Z-1.0
G01 Z-3.0
G0 Z0.0
Z-2.0
G01 Z-4.0
G0 Z0.0
Z-3.0
G01 Z-5.0
G0 Z0.0
Z-4.0
G01 Z-6.0
G0 Z0.0
Z-5.0
G01 Z-7.0
G0 Z5.0

X112.3 S1500 M3
Z2.0
G01 Z-1.0 F30.
G0 Z0.0
G01 Z-2.0
G0 Z0.0
Z-1.0
G01 Z-3.0
G0 Z0.0
Z-2.0
G01 Z-4.0
```

Fig.2: Path Simulation for drilling process

```
%_N_DUN004_MPF
G642 COMPCURV
FGROUP(X,Y,Z)
G0G90G54 X181. Y0. S1000 M3
Z2.0
G01 Z-1.0 F30.
G0 Z0.0
G01 Z-2.0
G0 Z0.0
Z-1.0
G01 Z-3.0
G0 Z0.0
Z-2.0
G01 Z-4.0
G0 Z0.0
Z-3.0
G01 Z-5.0
G0 Z0.0
Z-4.0
G01 Z-6.0
G0 Z0.0
Z-5.0
G01 Z-7.0
G0 Z5.0

X112.3 S1500 M3
Z2.0
G01 Z-1.0 F30.
G0 Z0.0
G01 Z-2.0
G0 Z0.0
Z-1.0
G01 Z-3.0
G0 Z0.0
Z-2.0
G01 Z-4.0
```

Fig.3: NC Program

Fig.4: Drilling holes on Aramid Fiber

Fig.5: Setting for drilling holes

Fig.6: Final Component with all drilled hole

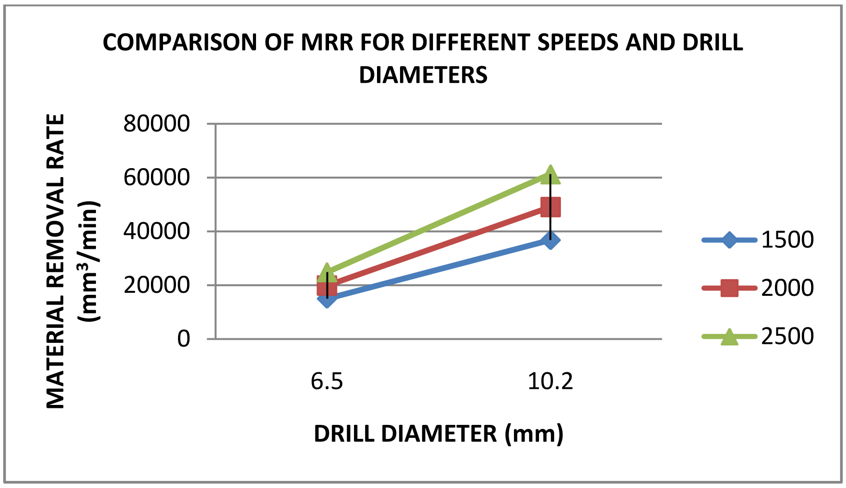


Fig.7: Comparision of MRR for different speeds and drill diameters

D. *Taguchi Parameter Design for Time Taken for Drilling ofAramid Fiber CompositeUsing MINITAB Software:*

1) **Procedure:**In order to identify the process parameters affecting the selected machine quality characteristics of drilling, the following process parameters are selected for the present work: Speed (A), Drill Angle (B). The selection of parameters of interest and their ranges is based on literature experiments conducted.

2) **Selection of Orthogonal Array:**The process parameters and their values are given in table. It was also decided to study the 2 – level and 2 -factor interaction effects of process parameters on the selected characteristics while drilling Aramid Fiber composite.

Factors	Process Parameters	Level 1	Level 2
A	SPEED (rpm)	1500	2500
B	CUTTER ANGLE (^{0})	118	120

3) **Results:** Using randomization technique, specimens were machined and time taken for drilling was measured. The experimental data for the time taken have been reported in Tables. Time taken 'smaller the better' type of machining quality characteristics, the S/N ratio for this type of response was and is given below:

$$\text{S/N ratio} = -10\log\left[\frac{1}{n}(y_1^2 + y_2^2 + \dots + y_n^2)\right] \qquad \dots (1)$$

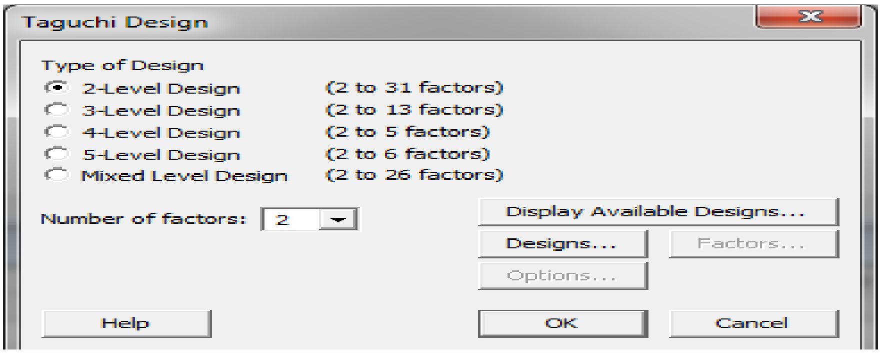
Where $y_1,\dots,y_n$ are the responses of the machining characteristics for each parameter at different levels. The feed rate is maintained constant. The experimentation is carried out using L4 orthogonal array in Taguchi Method as shown in Table.

4) **Observation:**

Cutter Data	Speed (Rpm)	Feed (Mm/Rev)	Time
118^0 – 6.5mm Drill	1500	0.3	2min 5secs
118^0 – 10.2mm Drill	1500	0.3	2min 10secs
118^0 – 6.5mm Drill	2000	0.3	2min
118^0 – 10.2mm Drill	2000	0.3	1min 57secs
118^0 – 6.5mm Drill	2500	0.3	1min 30secs
118^0 – 10.2mm Drill	2500	0.3	1min
120^0 – 6.5mm Drill	1500	0.3	2min 38secs
120^0 – 10.2mm Drill	1500	0.3	2min 35secs
120^0 – 6.5mm Drill	2000	0.3	2min 20secs
120^0 – 10.2mm Drill	2000	0.3	2min 11secs
120^0 – 6.5mm Drill	2500	0.3	2min
120^0 – 10.2mm Drill	2500	0.3	1min 10secs

E. *Optimizationfor 6.5mm DrillUsing Minitab Software:*

5) *Design of Orthogonal Array:* First Taguchi Orthogonal Array is designed in Minitab17 to calculate S/N ratio and Means which steps are given below:

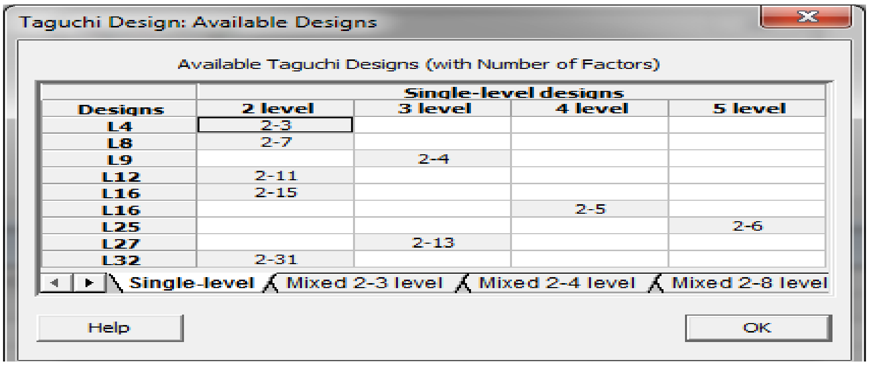


Type of Design

● 2-Level Design (2 to 31 factors)
○ 3-Level Design (2 to 13 factors)
○ 4-Level Design (2 to 5 factors)
○ 5-Level Design (2 to 6 factors)
○ Mixed Level Design (2 to 26 factors)

Number of factors: 2

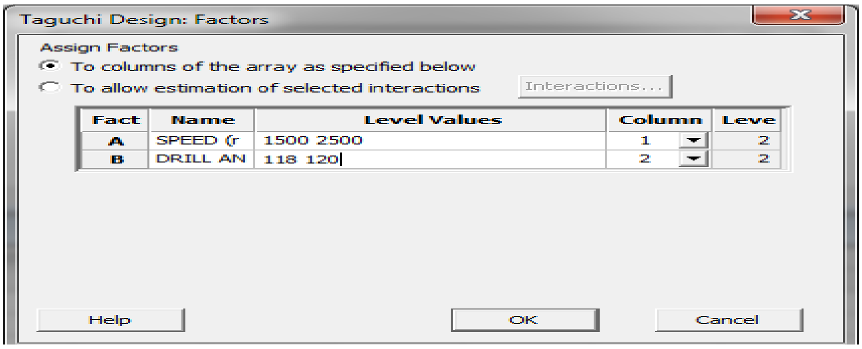
Display Availabe Designs – L9 – 2-3



Available Taguchi Designs (with Number of Factors)

	Single-level designs			
Designs	2 level	3 level	4 level	5 level
L4	2-3			
L8	2-7			
L9		2-4		
L12	2-11			
L16	2-15			
L16			2-5	
L25				2-6
L27		2-13		
L32	2-31			

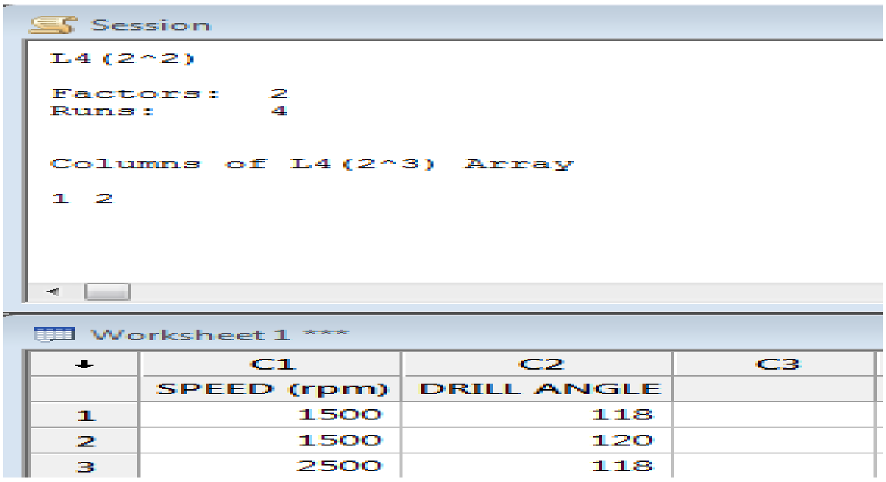
Available Designs



Assign Factors

● To columns of the array as specified below
○ To allow estimation of selected interactions

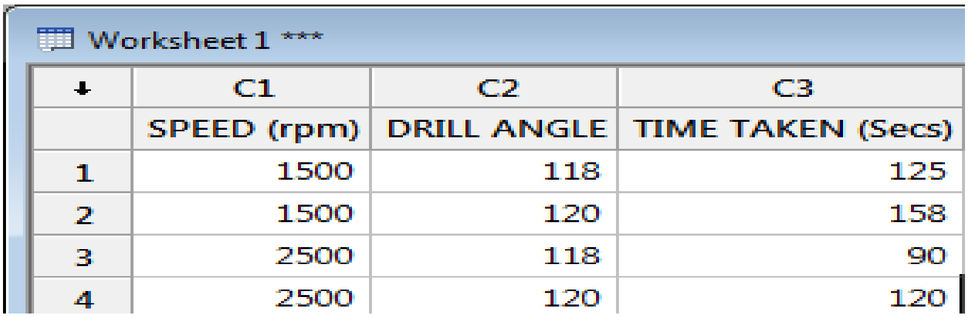
Fact	Name	Level Values	Column	Leve
A	SPEED (r	1500 2500	1	2
B	DRILL AN	118 120	2	2



```
L4(2^2)

Factors:  2
Runs:     4

Columns of L4(2^3) Array

1 2
```

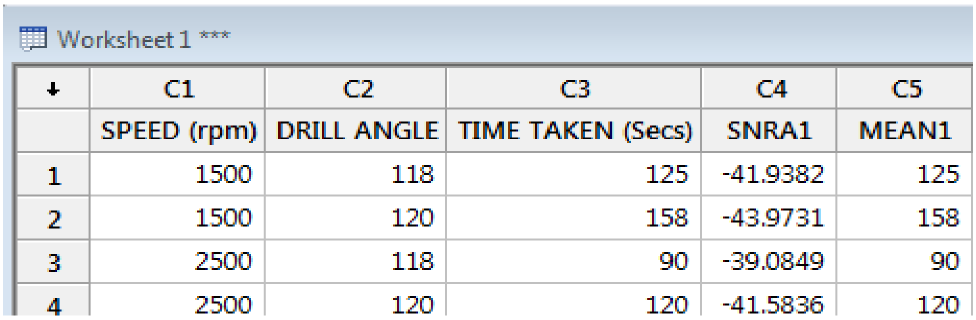
↓	C1	C2	C3
	SPEED (rpm)	DRILL ANGLE	
1	1500	118	
2	1500	120	
3	2500	118	

Factors



↓	C1	C2	C3
	SPEED (rpm)	DRILL ANGLE	TIME TAKEN (Secs)
1	1500	118	125
2	1500	120	158
3	2500	118	90
4	2500	120	120

Enter Time Taken



↓	C1	C2	C3	C4	C5
	SPEED (rpm)	DRILL ANGLE	TIME TAKEN (Secs)	SNRA1	MEAN1
1	1500	118	125	-41.9382	125
2	1500	120	158	-43.9731	158
3	2500	118	90	-39.0849	90
4	2500	120	120	-41.5836	120

Output-S/N Values

Fig.8. Steps for design of orthogonal array

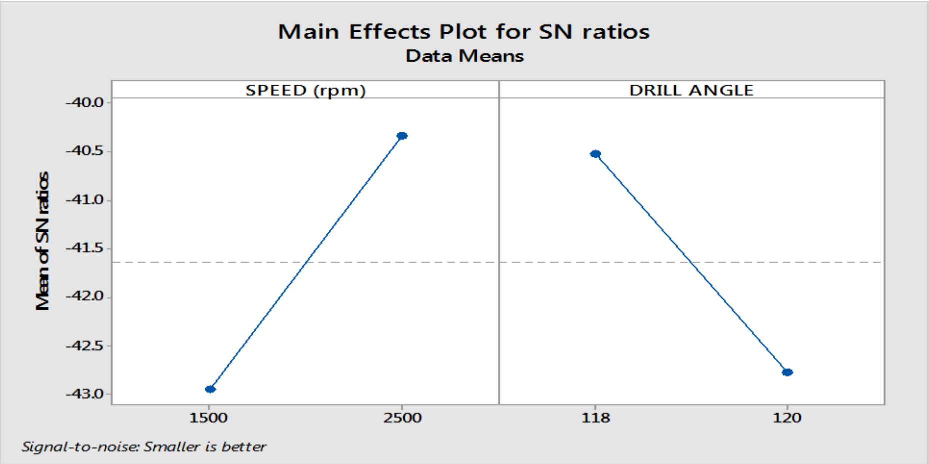


Fig.9. Effect of drilling parameters on time taken for S/N ratio

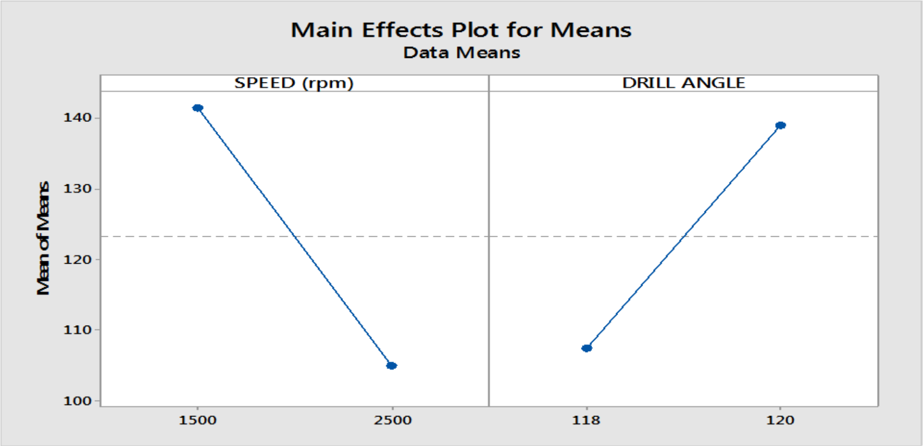
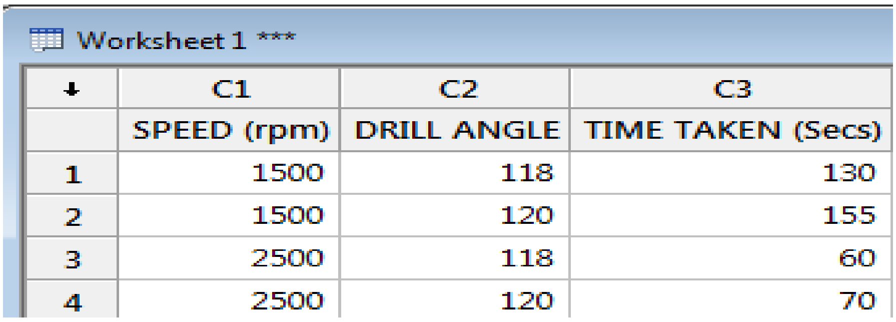


Fig.10. Effect of drilling parameters time taken for means

6) **Results:**Taguchi method stresses the importance of studying the response variation using the signal–to–noise (S/N) ratio, resulting in minimization of quality characteristic variation due to uncontrollable parameter. The time taken is considered as the quality characteristic with the concept of "the smaller-the-better".
7) **Analysis and Discussion:**Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

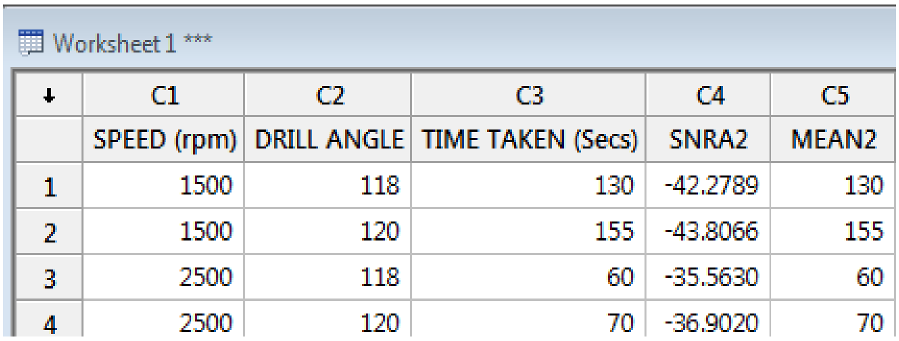
Speed: -The effect of parameter Speed on time taken is shown above figure for S/N ratio. Its effect is increasing with increase in speed. So, optimum speed is 2500rpm.
Cutter Angle: -The effect of parameter Drill angle on Time taken is shown above figure for S/N ratio. Its effect is decreasing with increase in Cutter angle. So, optimum drill angle is 118^0.

F. *Optimizationfor 10.2mm DrillUsing MINITAB Software*



↓	C1	C2	C3
	SPEED (rpm)	DRILL ANGLE	TIME TAKEN (Secs)
1	1500	118	130
2	1500	120	155
3	2500	118	60
4	2500	120	70

Enter Time Taken



↓	C1	C2	C3	C4	C5
	SPEED (rpm)	DRILL ANGLE	TIME TAKEN (Secs)	SNRA2	MEAN2
1	1500	118	130	-42.2789	130
2	1500	120	155	-43.8066	155
3	2500	118	60	-35.5630	60
4	2500	120	70	-36.9020	70

S/N Values

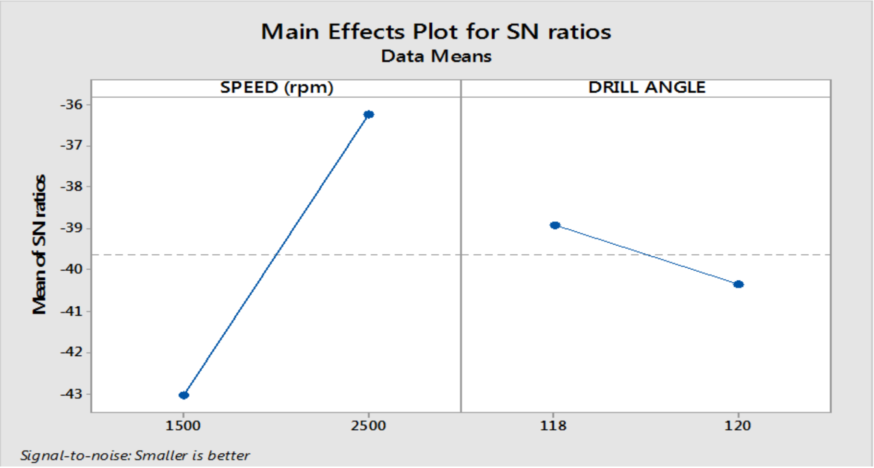


Fig.11. Effect of drilling parameters on time taken for S/N ratio

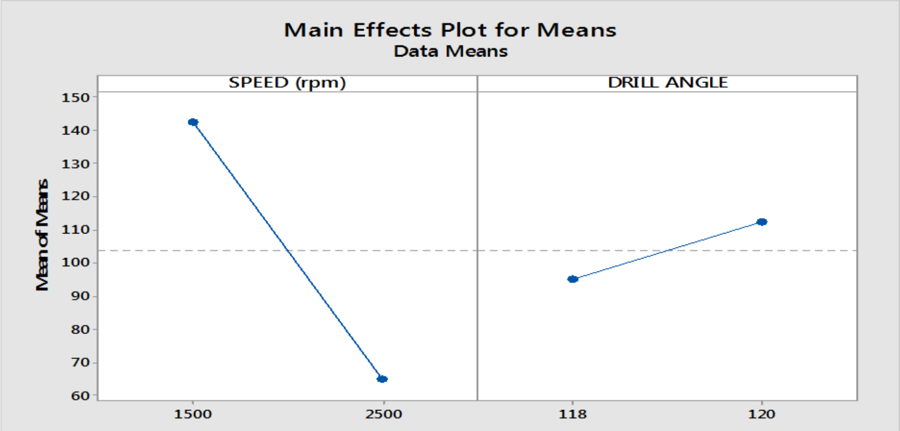


Fig.12. Effect of drilling parameters time taken for Means

8) **Analysis and Discussion:**Regardless of the category of the performance characteristics, a greater S/N value corresponds to a better performance. Therefore, the optimal level of the machining parameters is the level with the greatest value.

Speed: -The effect of parameter Speed on time taken is shown above figure for S/N ratio. Its effect is increasing with increase in speed. So, optimum speed is 2500rpm.

Cutter Angle: -The effect of parameter Cutter angle on Time taken is shown above figure for S/N ratio. Its effect is decreasing with increase in Cutter angle. So, optimum cutter point angle is 118^0.

IV. Structural Analysis

G. For 6.5mm Diameter – 118^0 Angle

→→Ansys → workbench→ select analysis system → static structural → double click

9) *For Aluminium*

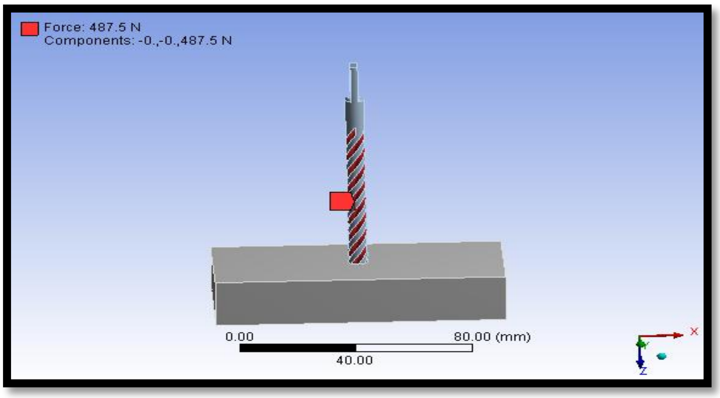


Fig.13. Force

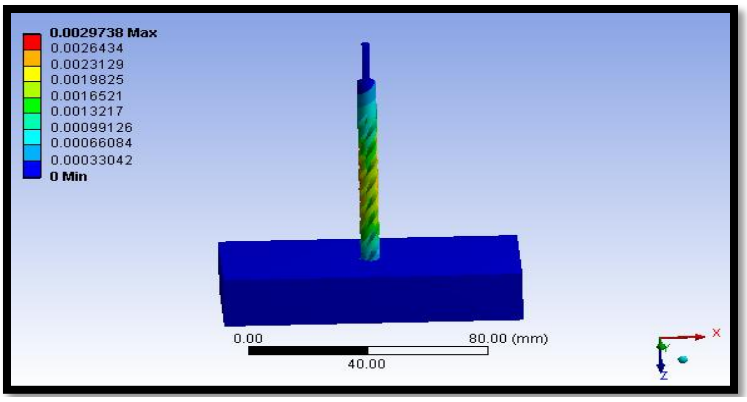


Fig.14. Deformation

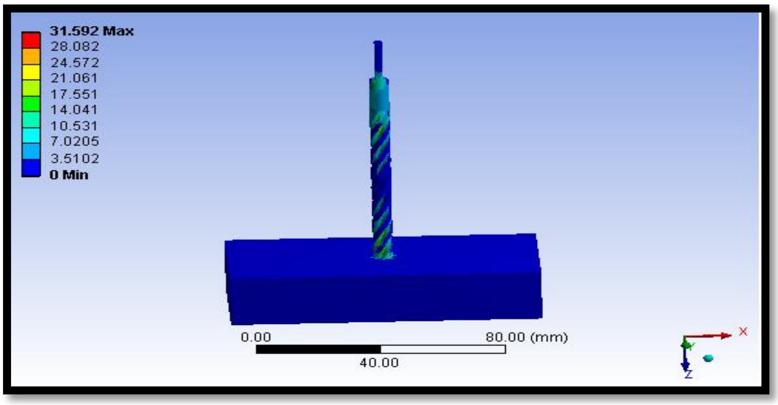


Fig.15.Stress

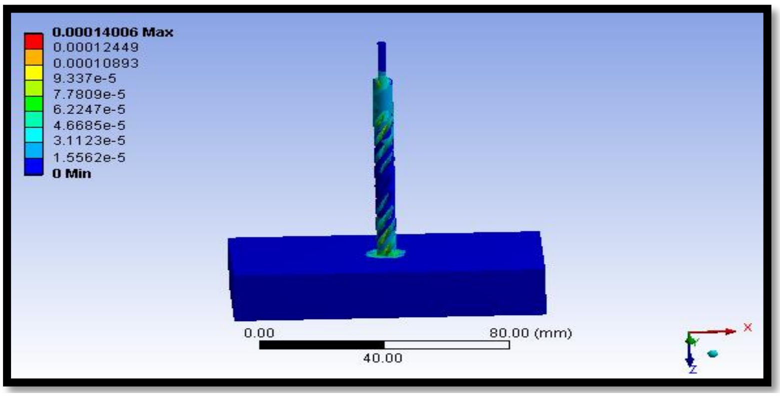


Fig.16. Strain

10) For Mild Steel:

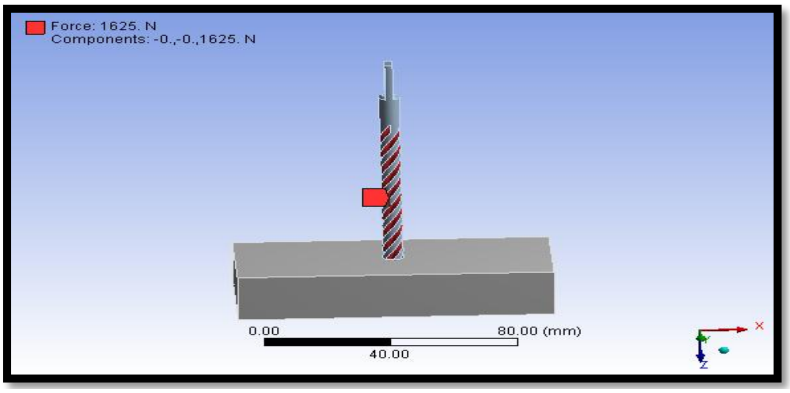


Fig.17. Force

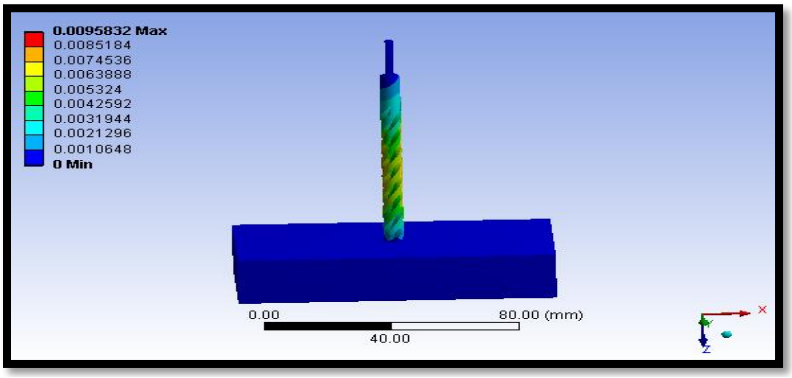


Fig.18. Deformation

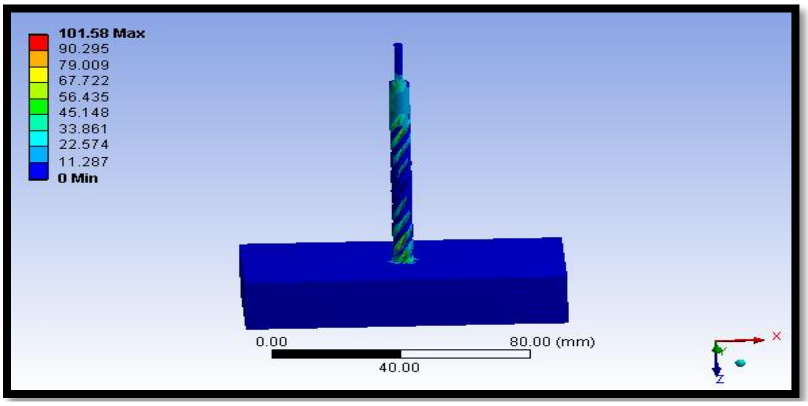


Fig.19.Stress

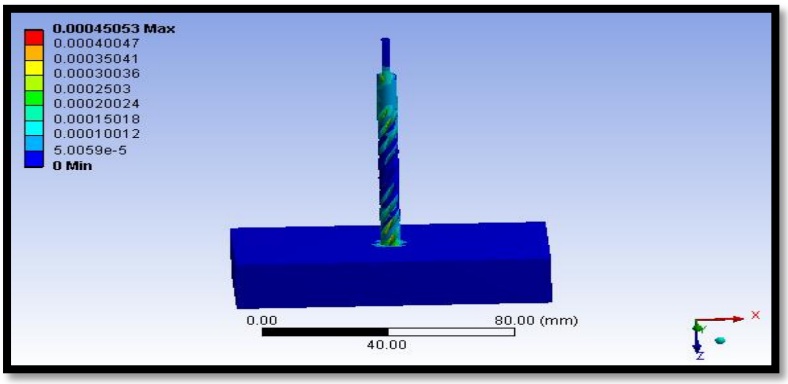


Fig.20.Strain

11) For Aramid Fiber:

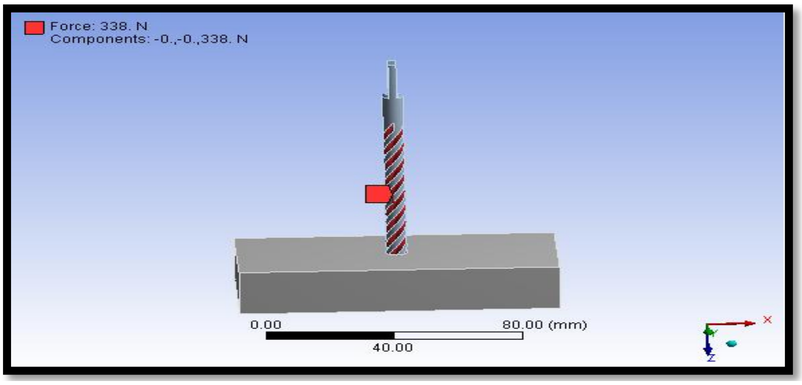


Fig.21.Force

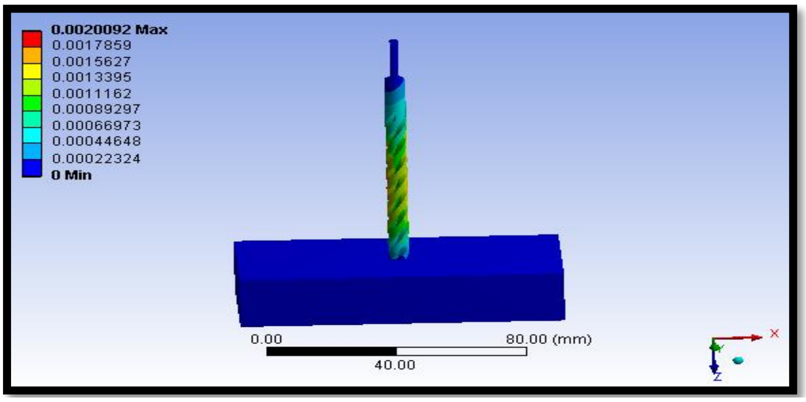


Fig.22. Deformation

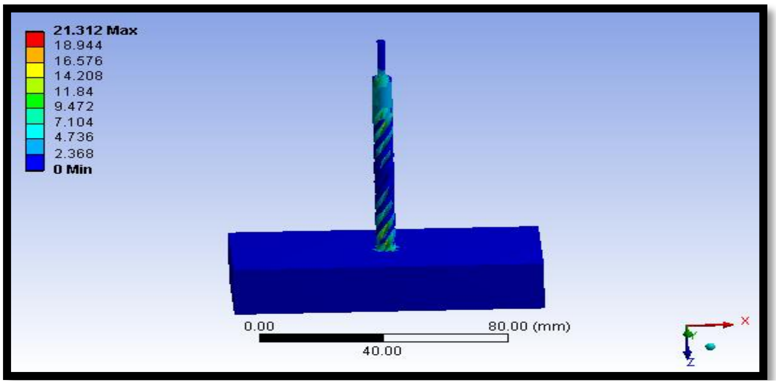


Fig.23. Stress

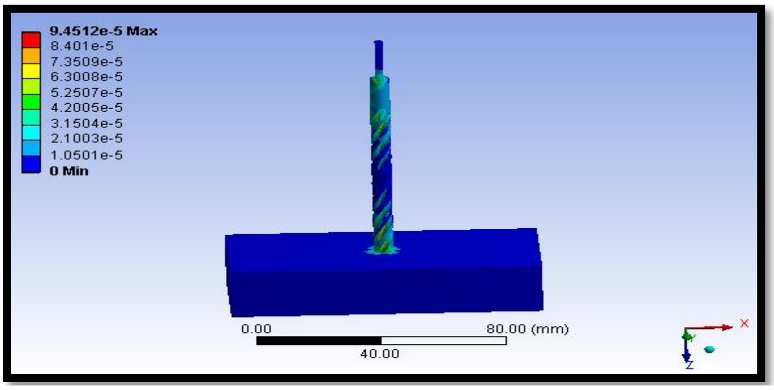


Fig.24. Strain

Similarly, Structural analysis is done

H. For 6.5mm Diameter and 120^0 Angle

I. For 10.2 mm Diameter and 118^0 Angle

J. For 10.2 mm Diameter and 120^0Angle

And results were found for Aluminium, Mild Steel and Aramid fiber

V.Results

K. For Drill diameter 6.5 mm

Angle		Aluminium	Mild steel	Aramid Fiber
118^0	Deformation(mm)	0.0029738	0.0095832	0.0020092
	Stress (MPa)	31.592	101.58	21.312
	Strain	0.00014006	0.00045053	$9.4512e^{-5}$
120^0	Deformation(mm)	0.0029475	0.0095038	0.0019921
	Stress (MPa)	30.033	100.29	20.861
	Strain	0.00012862	0.00042964	$8.936\ e^{-5}$

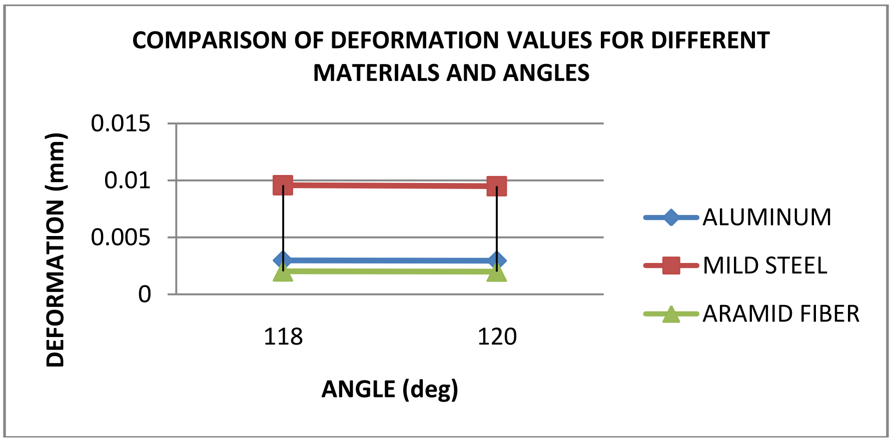


Fig.25. Comparision of deformation values for different materials and angles

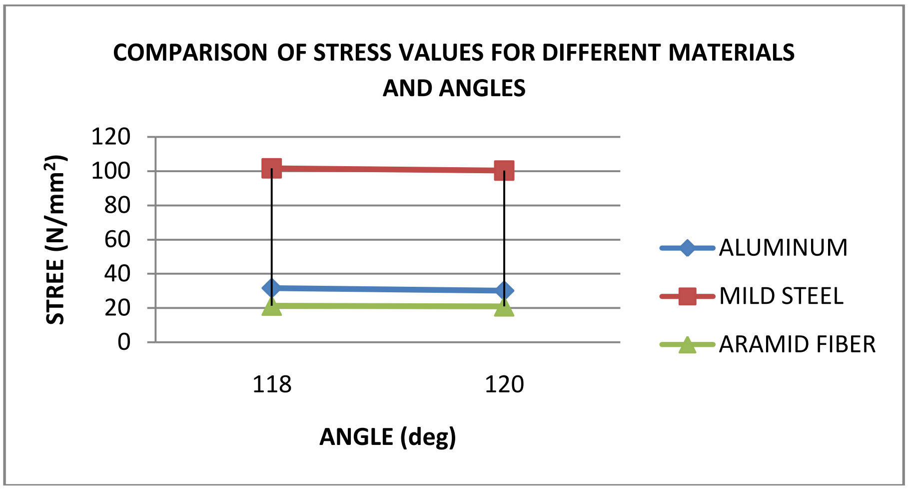


Fig.26. Comparision of stress values for different materials and angles

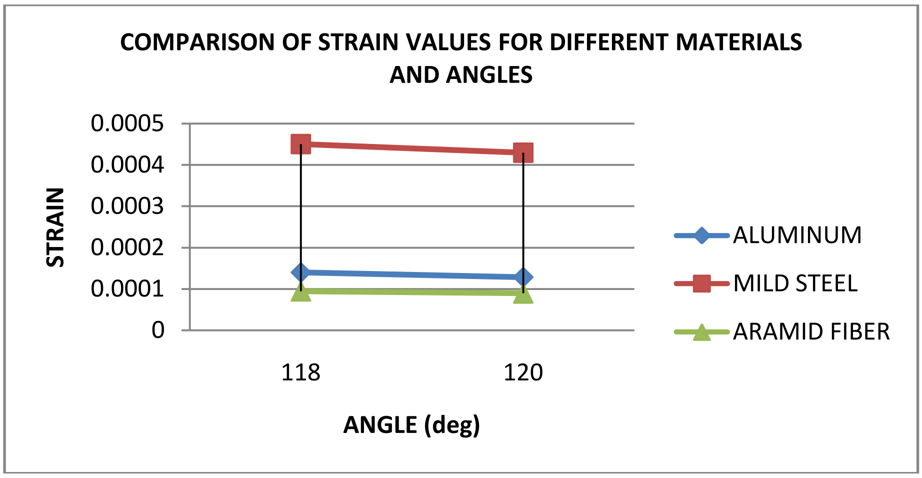


Fig.27. Comparision of strain values for different materials and angles

L. For Drill diameter 10.2 mm

Angle		Aluminium	Mild steel	Aramid Fiber
118^0	**Deformation(mm)**	0.00093653	0.0027798	0.00059487
	Stress (MPa)	10.81	32.082	6.9293
	Strain	5.5479 e^{-5}	0.00017039	3.6143 e^{-5}
120^0	**Deformation(mm)**	0.00097342	0.0028515	0.00061191
	Stress (MPa)	14.574	57.688	11.102
	Strain	9.981 e^{-5}	0.00026923	5.1573 e^{-5}

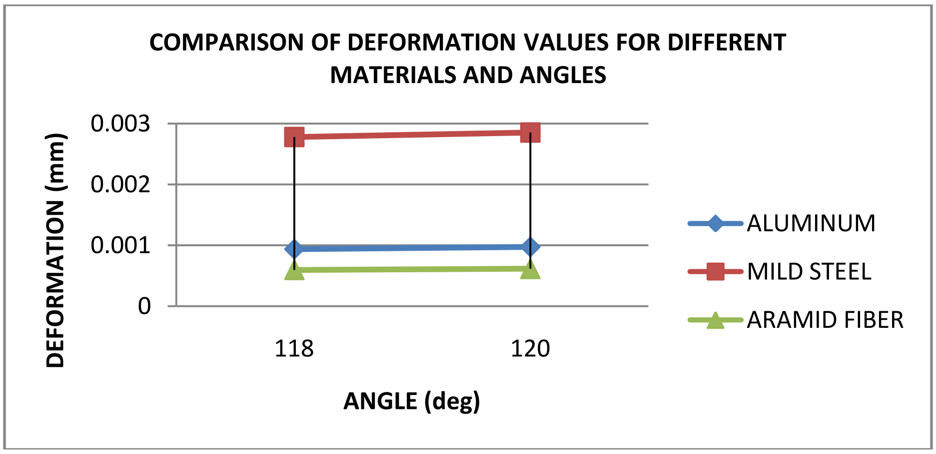


Fig.28. Comparisionofdeformation values for different materials and angles

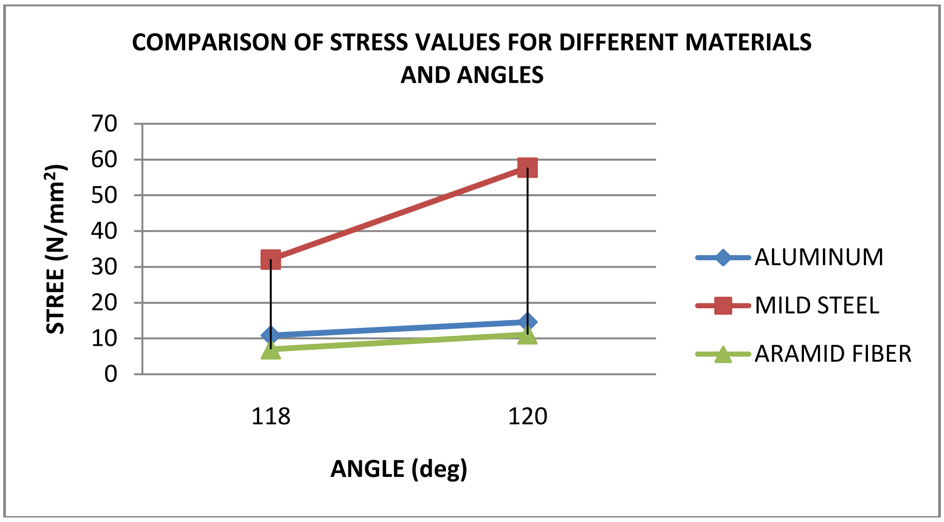


Fig.29. Comparision of stress values for different materials and angles

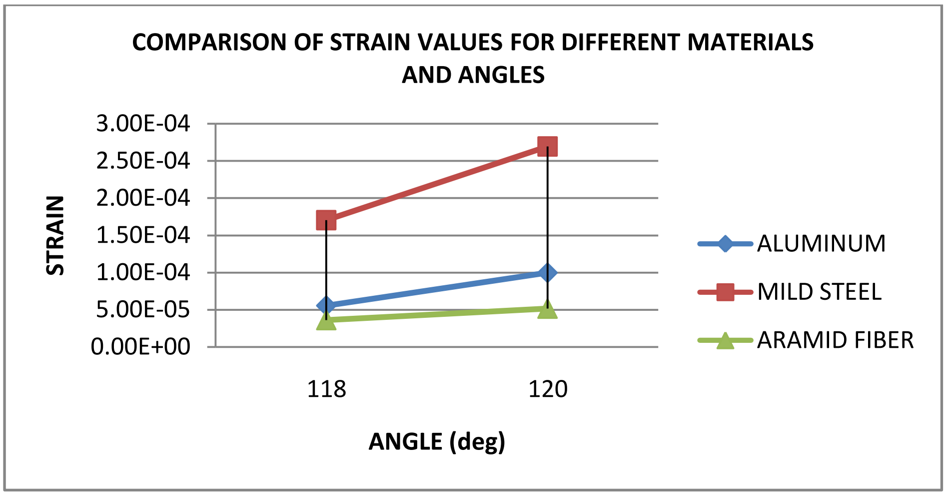


Fig.30. Comparision of strain values for different materials and angles

VI. Conclusions

In the present research work, drilling operations were conducted on the Aramid Fiber with 6.5mm and 10.2mm diameter drills with 118^0 and 120^0 point angles with different cutting parameters. The cutting parameters are spindle speed – 1500rpm, 2000rpm and 2500rpm, Feed – 0.3mm/rev.By observing the experimental results, the time taken for drilling is less for 118^0 at 2500rpm speed. Material removal rates are determined by varying the above parameters. By observing the results, the material removal rate is more for high speed 2500rpm for 10.2mm drill.

Based on the Taguchi results to optimize parameters for time taken for drilling, the optimum speed is 2500rpm and drill point angle is 118^0.Cutting forces and thrust forces are calculated using theoretical calculations. 3D modeling is done in Pro/Engineer and analysis is done in Ansys for materials Aluminum, Mild Steel and Aramid Fiber.By observing the results, the stresses are more for 120^0 angle and 6.5mm diameter. The deformation, stress and strain are found less when drilling composite material Aramid Fiber.

References

[1]. Biren Desai, Jaypalsingh Rana, Hiren Gajera, Study Of Hole Quality Parameters In Drilling Of Carbon Fiber Reinforced Plastics (Cfrp) Using Design Of Experiments, Journal Of Information, Knowledge And Research In Mechanical Engineering, Issn 0975 – 668x| Nov 12 To Oct 13 | Volume – 02, Issue – 02

[2]. P. Ghabezi, M. Khoranb A, Optimization Of Drilling Parameters In Composite Sandwich Structures (Pvc Core), Indian J.Sci.Res. 2(1): 173-179, 2014 Issn: 2250-0138 (Online), Issn: 0976-2876(Print)

[3]. R.M. Kulkarni, H. N. Narasimha Murthy, G.B.Rudrakshi, Sushilendra, Effect Of Drilling Parameters In Drilling Of Glass Fiber Reinforced Vinylester/Carbon Black Nanocomposites, International Journal Of Scientific & Technology Research, Volume 3, Issue 7, July 2014 Issn 2277-8616

[4]. J Babu, Tom Sunny, Optimization Of Process Parameters In Drilling Of Gfrp Composites Drilled By An End Mill, October 2013, Researchgate

[5]. S. Madhavan, S. BalasivanadhaPrabhu “Experimental Investigation And Analysis Of Thrust Force In Drilling Of Carbon Fibre Reinforced Plastic Composites Using Response Surface Methodology”, International Journal Of Modern Engineering Research (Ijmer) Vol.2, Issue.4, (July-Aug. 2010.2) Pp.2719-2723