Machinability Study of Drilling Parameters on Al Alloy

Janardhana H
UG Scholar
Department of Mechanical Engineering
PESITM – Shivamogga.

Ashok R. Banagar
Asst. Prof., PESITM,
Shivamogga, INDIA

Ganesh U. L.
Asst. Prof., PESITM,
Shivamogga, INDIA

Vinod V. Rampur
Asst. Prof., PESITM,
Shivamogga, INDIA

Abstract **- In this paper the drilling of Al 7050 aluminium alloy with the help of radial drilling machine operation with tool use high speed steel by applying taguchi methodology has been reported. The purpose of this paper is to investigate the influence of cutting parameters, such as cutting speed and feed rate, and point angle on surface roughness, hole diameter error produced when drilling Al 7050 aluminium alloy. A plan of experiments, based on L9 taguchi design method, was made and drilling was done with the selected cutting parameters. All tests were run at cutting speeds of 200, 250, and 315 r.p.m. and feed 0.13, 0.18, and 0.25 mm/rev and point angle of 104°, 118°, and 132°. The orthogonal array, signal-to-noise ratio, and analysis of variance (ANOVA) helps in deciding optimal conditions for drilling.**

I. INTRODUCTION

A. Drilling

Nowadays Drilling is one of the most important material removal processes that have been widely used in the aerospace, aircraft and automotive industries. Although modern metal-cutting methods, including electron-beam machining, ultrasonic machining, electrolytic machining and abrasive jet machining, have improved in the manufacturing industry, conventional drilling still remains one of the most common machining processes.

Different tools and methods are used for drilling depending on the type of material, the size of the hole, the number of holes, and the time to complete the operation. It is most frequently performed in material removal and is used as a preliminary step for many operations; Figure 1 shows the drilling operation on to the work piece.

Several factors influence the quality of drilled holes. The most obvious once are the cutting conditions (cutting speed and feed rate) and cutting configuration (tool material, diameter and geometry).The quality of the drilled holes depends on the Thrust force and torque generated during drilling, which in turn affected by factors such as, cutting speed, feed rate, tool geometry etc. Higher the value of thrust force and torque higher the value of work damage and tool wear. The efficient economic machining of the material is required for the desired dimensions and surface finish. Taghuchi technique is powerful tool in experiment design and provides simple, efficient and systematic approach for optimization of process parameters.

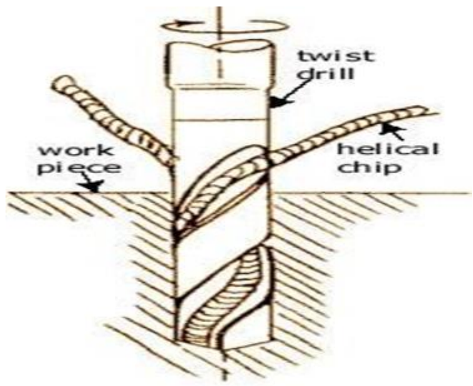


Fig 1: Drilling operation on the work piece

B. Aluminum Alloys

Aluminum is used in many industrial areas to make different products and it is significant for the world economy. Structural components made from aluminum and aluminum alloys are vital in the aerospace industry and very important in other areas of transportation and building in which durability, strength and light weight are expected. Many engineering materials have limitation in achieving good combination of strength, stiffness, toughness, and density. To overcome these short comings and meet the ever increasing demand of modern day technology, Al alloys are most promising materials of recent interest. Lightweight materials such as Al alloys are used in modern aerospace structure due to their best combination of metallurgical and physical properties.

The present work is to present an effective approach for the optimization of Drilling parameters with multiple performance characteristics based on the Taguchi method. The experiment will be carried out by varying the cutting speed, feed rate and drill point angle optimized with considerations of multiple performance characteristics such as surface roughness, diametric error and MRR.

C. Taguchi Analysis

Taguchi has developed a methodology for the application of factorial design experiments that has taken the design of experiments from the exclusive world of the statistician and brought it more fully in to the world of manufacturing. Thus the marriage of design of experiments with optimization of control parameters to obtain best results is achieved in Taguchi method. Orthogonal arrays provide a set of well-balanced experiments & desired output. Conventional procedures need more number of experiments to be performed, when more number of parameters increased, this issue is resolved by Taguchi method it uses a special design to study the parameters with small number of experiments.

II. METHODOLOGY

The machining parameters are determined by using Taguchi design method. Orthogonal arrays of Taguchi, the signal-to-noise (S/N) ratio, the analysis of variance (ANOVA), and regression analysis are used to get the optimal levels and to analyze the effect of machining parameters on material removal rate, surface Roughness, Thrust force and Torque.

A. Taguchi Method

Taguchi has developed a methodology for the application of factorial design experiments that has taken the design of experiments from the exclusive world of the statistician and brought it more fully in the world of manufacturing. Thus the marriage of design of experiments with optimization of control parameters to obtain the best results is achieved in Taguchi method. Orthogonal arrays provide a set of well-balanced experiments & desired output.

Conventional procedure needs more number of experiments to be performed, when more number of parameter increased, this issue is resolved by Taguchi method, it uses special design to study the parameters with small number of experiments saving time, cost and finding significant factors at more ease. Taguchi uses the S/N ratio to measure the quality characteristic deviating from the desired value. There are several S/N ratios available, depending on the type of characteristic, lower the better, nominal the best or higher the better.

The S/N ratio for the higher the better criterion given by Taguchi as:

$$\frac{S}{N} = -10\log_{10}\left[\frac{1}{n}\sum\frac{1}{y^2}\right] \text{ ----------------- } 2.1$$

The S/N ratio for the lower the better criterion given by Taguchi as:

$$\frac{S}{N} = -10\log_{10}\left[\frac{\sum y^2}{n}\right] \text{ -------------------- } 2.2$$

Where ‘y’ is the observed data and ‘n’ is the number of observations. Regardless of category of the performance characteristics, a grater S/N value corresponds to a better performance. Therefore, the optimal level of machining parameters is the level with the great S/N ratio value.

B. Analysis of Variance (ANOVA)

ANOVA is a statistical process in which the existence of differences among several of population means determined. While the aim of ANOVA is the detect difference among several population means, the technique requires the analysis of different forms of variance associated with the random samples under study-hence the name analysis of variance.

C. Regression Analysis

Is a statistical tool that allows you to examine how multiple independent variables are related to a dependent variable. Once you are identified how these multiple variables relate to your dependent variable, you can take information about all of the independent variables and use it to make much more powerful and accurate predictions about why thinks are the way they are. It is also used to understand which among the independent variables are related to the dependent variable and to explore the form of these relationships. The general form of multiple regression models is as follows:

Independent variable = b_0+b_1 (variable 1) +b_2 (variable 2) +…. + ϵ.

Where b_1, b_2 ….. Are estimates of the dependent variable 1, 2…..and is the error

III. DESIGN OF EXPERIMENT

In this study, three machining parameters were selected as control factors, and each parameter was designed to have three levels, denoted 1, 2, and 3 (Table 3.1). The experimental design was according to an L9) array based on
Taguchi method, while using the Taguchi orthogonal array would markedly reduce the number of experiments. A set of experiments designed using the Taguchi method was conducted to investigate the relation between the process parameters and Surface roughness, Hole diameter error and Burr height. DESIGN EXPERT @ 16 minitab software was used for regression and graphical analysis of the obtained data.

Table 3.1: Deciding the Process variables and their limits

Value in coded form	Process variables		
	Point angle	Cutting speed in rpm	Feed rate (mm/rev)
1	104°	200	0.13
2	118°	250	0.18
3	132°	315	0.25

IV. EXPERIMENTAL WORK

The work piece material selected for investigation is the aluminium alloy Al 7050.

A. Work Piece:

Drilling experiments has been carried out on aluminium alloy 7050. Work piece chemical composition mentioned below in table 4.1.

Table 4.1: Chemical composition in (wt%) of Al 7050:

Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Zr	Al
0.12	0.15	2 – 2.6	0.1	1.9-2.6	0.04	5.7-6.7	0.06	0.08-0.15	Remainder

<u>Process Parameters</u>: The following are some process parameters in turning and machining which affect performance of machining.

Cutting Speed (N), Feed (f), and Point angle (θ)

ISSN: 2278-0181
NCMPC - 2019 Conference Proceedings

Performance Parameters:

$$MRR = \left((\pi/4) \times D^2 \times f \times N \right) \text{(mm}^3\text{/sec)}$$

Where,

D – Diameter of work piece,
f – Feed and
N – Speed in rpm

B. Orthogonal Arrays

In order to reduce the total number of experiments "Sir Ronald Fisher" has developed the solution: "Orthogonal Arrays". Taguchi employs design experiments using specially constructed table, known as "Orthogonal Arrays" (OA) to treat the design process, such that the quality is built into the product during the product design stage.

Typical Orthogonal Array

In this array, the columns are mutually orthogonal. That is for any pair of columns all combination of factors occurs and they occur an equal number of times. It can be seen that there are three parameters, A, B and C each at three levels. This is called an 'L_9' design; with the 9 indicates the nine rows, configurations, or prototypes to be tested. Specific test characteristics for each experimental evaluation are identified in the associated row of the table. Thus ' L_9 (3^3) means that nine experiments are to be carried out to study three variables with three levels. This design 27 (3^3) configuration reduces to 9 experimental evaluations as shown in Table – 4.3. There are greater savings in testing for larger arrays.

C. Plan of Experiments Based on Taguchi Method

For the experimental plan, the Taguchi method is used for three levels with careful understanding of the parameters.

i) Selection of Orthogonal Array

In the present research, three parameters such as speed, feed, and point angle are considered. Each of these parameters is varied at three levels as shown in Table 4.2. The appropriate orthogonal array for three parameters each at three levels is chosen from taguchi array selector. The appropriate orthogonal array for the present research is L9. Therefore, the plan is made for 9 experiments to be conducted.

The outputs to be studied are Material Removal Rate (MRR), surface roughness, thrust force, and torque.

Table 4.2: Orthogonal Array Selector

		Number of Parameters																													
		2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
LEVELS	2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16	L16	L16	L16	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32	L32
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27	L27	L36	L36	L36	L36	L36	L36	L36	L36	L36	L36								
	4	L16	L16	L16	L32	L32	L32	L32	L32																						
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50																			

Table 4.3: L_9 Orthogonal array

Sl. No	Cutting speed in rpm	Feed rate (mm/rev)	Point angle
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

The experiment has been conducted as per the L_9 orthogonal array and the work piece after the experiment has shown in below figure 2.

Before Experimentation

After Experimentation

Fig. 2: Al 7050 Work piece before and after the experiment

V. RESULTS AND DISCUSSION

This section includes the analysis and interpretation of the experimental results to improve the performance characteristics of the turning process. The decisions are made with the assistance of following analytical techniques:

a. Column effect method
b. Plotting by levels method
c. Analysis of variance

A. Analysis using column effect method

This approach is used to subjectively point out column which has large influence on the response. Data associated with first, second and third levels are noted and difference of largest and smallest of the three levels represent "delta". The magnitudes of differences are compared to each other, to find out the relatively strong control factors. The relative magnitudes (the plus or minus sign shows positive or negative correlation with level numbers, respectively) indicate the relative power of the factors affecting the result as shown in Table – 5.1.

Table 5.1: Analysis of MRR – Al 7050

Si No	Point angle(θ)	Cutting speed in rpm	Feed rate (mm/rev)	MRR (mm^3/sec)	S/N Ratio (db)
1.	104	200	0.13	34	30.6295
2.	118	200	0.18	47	33.4419
3.	132	200	0.23	65	36.2582
4.	118	250	0.13	42	32.4649
5.	132	250	0.18	58	35.2685
6.	104	250	0.23	81	38.1697
7.	132	315	0.13	53	34.4855
8.	104	315	0.18	74	37.3846
9.	118	315	0.23	103	40.2567

Table 5.2: Analysis of Surface roughness (SR) - Al 7050

SL No.	Point angle(θ)	Cutting speed in (rpm)	Feed rate (mm/rev)	Al 7050	
				SR (μm)	S/N Ratio (db)
1	104	200	0.13	1.321	-2.418
2	118	200	0.18	1.372	-2.747
3	132	200	0.23	2.548	-8.123
4	118	250	0.13	1.569	-3.912
5	132	250	0.18	1.992	-5.985
6	104	250	0.23	2.817	-8.995
7	132	315	0.13	1.705	-4.634
8	104	315	0.18	1.466	-3.322
9	118	315	0.23	2.671	-8.533

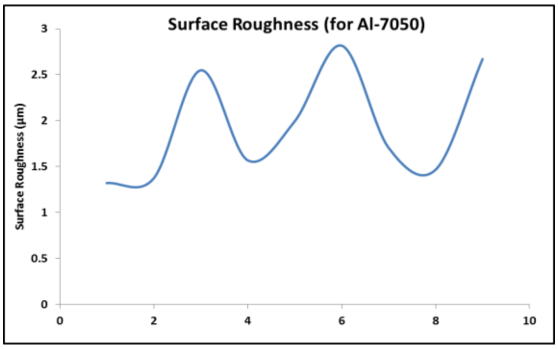


Fig. 3: variation of surface roughness

Figure 3 shows the variations in the surface roughness in the aluminum alloys after conducting the drilling experiment.

Table 5.3: Analysis of Thrust force on Al7050

SL No.	Point angle (θ)	Cutting speed in (rpm)	Feed rate (mm/rev)	Al 7050	
				Thrust force (N)	S/N Ratio (db)
				608	-55.678
2	118	200	0.18	1687	-64.542
3	132	200	0.23	1000	-60.000
4	118	250	0.13	1500	-63.521
5	132	250	0.18	784	-57.886
6	104	250	0.23	735	-57.325
7	132	315	0.13	549	-54.791
8	104	315	0.18	1088	-60.732
9	118	315	0.23	1903	-65.588

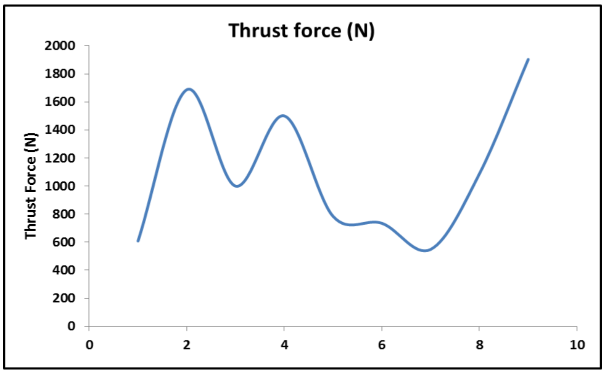


Fig. 4: variation of Thrust force in Al7050

Figure 4 shows the variations in the Thrust force in the aluminum alloys after conducting the drilling experiment.

Table 5.4: Analysis of Torque on Al7050

SL No.	Point angle (θ)	speed in (rpm)	Feed rate (mm/rev)	Al 7050	
				Torque (N-M)	S/N Ratio (db)
1	104	200	0.13	0.7	3.098
2	118	200	0.18	0.6	4.436
3	132	200	0.23	1.6	-4.082
4	118	250	0.13	1.2	-1.583
5	132	250	0.18	1.5	-3.521
6	104	250	0.23	0.7	3.098
7	132	315	0.13	1.1	-0.827
8	104	315	0.18	1.1	-0.827
9	118	315	0.23	2.2	-6.848

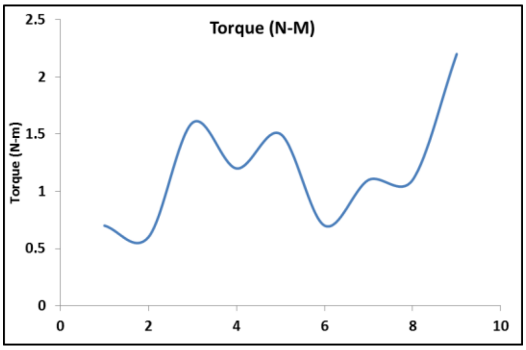


Fig. 5: variation of torque in Al7050

Figure 5 shows the variations in the Torque in the aluminum alloys after conducting the drilling experiment.

B. Analysis using Plotting by levels method

In this method, the average result for each level is calculated to plot the effect of influential factors. The sum of data associated with each level in the orthogonal array (OA) column divided by numbers of test (data point) for that will provide the appropriate averages. The factor strengths are directly proportional to the slope of the graphs.

Table 5.5: S/N ratio response table for MRR (Larger is better) – Al 7050

Factors/Levels	Level 1	Level 2	Level 3	Delta	Rank
Point angle (θ)	35.39	35.39	35.34	0.06	3
Cutting speed in (rpm)	33.44	35.30	37.34	3.93	2
Feed rate (mm/rev)	32.53	35.37	38.23	5.70	1

Table 5.6: S/N ratio response table for Surface Roughness of Al 7050

Level	speed	feed	Point angle
1	-4.430	-3.655	-4.912
2	-6.298	-4.019	-5.064
3	-5.497	-8.551	-6.248
Delta	1.868	4.896	1.336
Rank	2	1	3

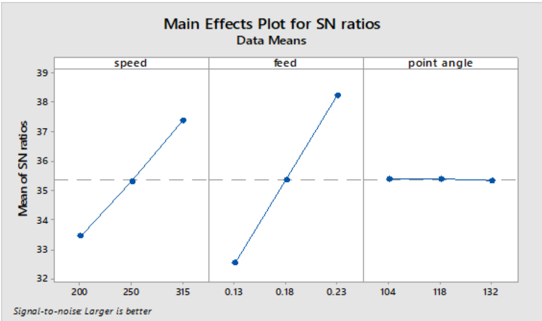
The analysis was made using popular software specifically used for the design of experiment applications known as MINITAB 18.

Table 5.7: S/N ratio response table for Thrust force (smaller is better) of Al 7050

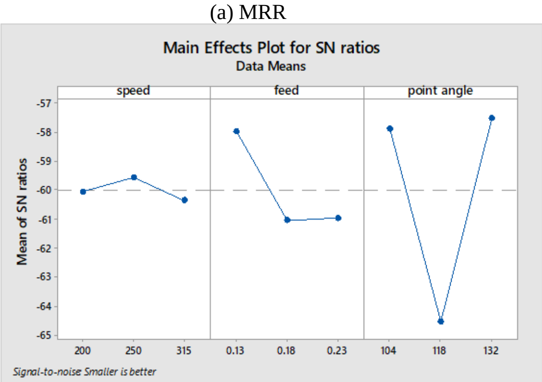
Level	speed	feed	Point angle
1	-60.07	-58.00	-57.91
2	-59.58	-61.05	-64.55
3	-60.37	-60.97	-57.56
Delta	0.79	3.06	6.99
Rank	3	2	1

Table 5.8: S/N ratio response table for Torque (smaller is better) of Al 7050

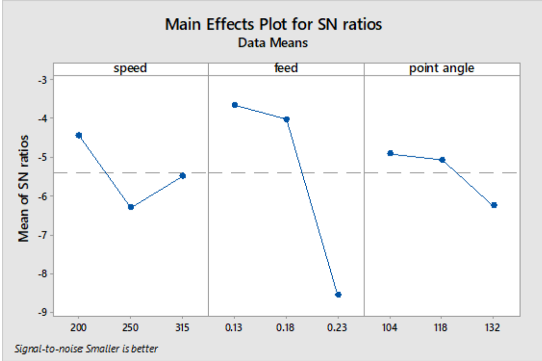
Level	speed	feed	point angle
1	1.15087	0.22885	1.78941
2	-0.66914	0.02910	-1.33170
3	-2.83472	-2.61094	-2.81069
Delta	3.98559	2.83979	4.60010
Rank	2	3	1



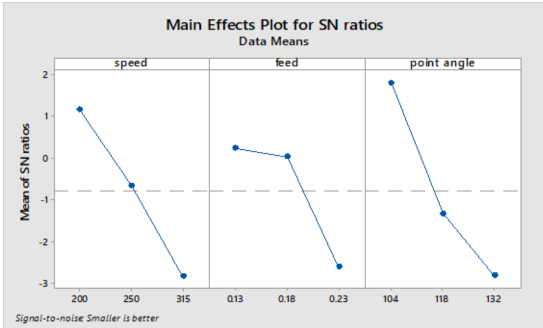
(a) MRR



(b) Thrust Force



(c) Surface roughness



(d) Torque

Fig. 6: Main effect plot for Al 7050

C. Analysis of Variance (ANOVA)

ANOVA is a statically based, objective decision making tool for detecting any differences in average performance of groups of items tested. In this experiment, both the allocation of the experimental material and the order in which the individual trials of the experiment are to be performed and randomly determined because ANOVA requires that the observations or error be independently distributed random variables. Confidence level of 95% was used throughout analysis of the experiment. From the statistical point of view, it is highly recommended to examine these residuals for normality and constant variance when using ANOVA.

Table 5.9: Analysis of Variance: MRR versus speed, feed, point angle for Al7050

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% of SS
speed	2	1186.89	593.44	27.25	0.035	32
feed	2	2422.22	1211.11	55.61	0.018	65.23
point angle	2	48.22	24.11	1.11	0.475	1.32
Error	2	43.56	21.78	-	-	-
Total	8	3700.89	-	-	-	98.53

Table 5.10: Analysis of Variance: SR versus speed, feed, point angle for Al7050

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% of SS
speed	2	0.21570	0.10785	7.31	0.120	7.70
feed	2	2.46379	1.23190	83.48	0.012	88.01
point angle	2	0.09018	0.04509	3.06	0.247	3.2216
Error	2	0.02951	0.01476	-	-	-
Total	8	2.79918	-	-	-	98.93

Table 5.11: Analysis of Variance: Thrust force versus speed, feed, point angle for Al7050

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% o SS
speed	2	45294	22647	0.71	0.584	2.33
feed	2	198023	99011	3.12	0.243	10.21
point angle	2	1631215	815607	25.69	0.037	84.16
Error	2	63502	31751	-	-	-
Total	8	1938033	-	-	-	97

Table 5.12: Analysis of Variance: Torque versus speed, feed, point angle for Al7050

Source	DF	Adj SS	Adj MS	F-Value	P-Value	% of SS
speed	2	0.3889	0.1944	0.54	0.650	18.26
feed	2	0.4422	0.2211	0.61	0.620	30.77
point angle	2	0.5756	0.2878	0.80	0.557	27
Error	2	0.7222	0.3611	-	-	-
Total	8	2.1289	-	-	-	76.03

D. Regression Analysis

Is a statistical tool that allows you to examine how multiple independent variables are related to a dependent variable. Once you are identified how these multiple variables relate to your dependent variable, you can take information about all of the independent variables and use it to make much more powerful and accurate predictions about why thinks are the way they are.

(i) Regression Equation for Al 7050:

SR = -1.4 + 0.00152 Speed + 11.47 Feed + 0.0076 Point angle

MRR = -54.0 + 0.2439 Speed + 400.0 Feed - 0.155 Point angle

THRUST = 438 + 0.81 Speed + 3270 Feed -1.2 Point angle

TORQUE = -3.22 + 0.00439 Speed + 5.00 Feed + 0.0202 Point angle

E. Confirmation Experiment

A confirmation experiment is performed by conducting a test using a specific combination of the factors and levels previously evaluated. The final step of the Taguchi's parameter design after selecting the optimal parameters is to predict and verify the improvement of the performance characteristics with the selected optimal machining parameters. The predicted S/N ratio using the optimal levels of the machining parameters is calculated with the help of following prediction equation:

Independent variable = b_0+b_1 (independent variable 1) +b_2 (independent variable 2) +…. + ∈

Where b_1, b_2 are estimates of the dependent variable 1, 2…..and ε is the error

Table 5.13: Confirmation experiment result for Aluminium

Exp no	Response parameter	Optimum machining parameters			MRR in (mm^3/Sec)		Error %
		Point angle	Cutting speed in rpm	Feed rate	Predicted	Expt.	
1	MRR	118	315	0.25	104.53	103	1.47

VI. CONCLUSION

Taguchi method is applied to find the optimal process parameters to maximize material remover rate and to minimize the thrust force, torque, and surface roughness for drilling of Al 7050 alloy. Taguchi orthogonal array, S/N ratio and ANOVA are used for optimization of cutting parameters. The following are the important conclusions can be drawn from the present work.

- From table 5.5 it is concluded that from the experimental results show that the order of priority, for performance characteristic MRR are: **feed rate, cutting speed and point angle** has the lowest effect on MRR.
- An experiment is also conducted to verify the effectiveness of Taguchi optimization method for Al 7050 alloy and also surface roughness, thrust force values are shown.

REFERENCE

[1] B.M Umesh gouda et al, " optimization of process parameter in drilling AL-S13N4 metal matrix composites material using taguchi technique " international conference on advances in manufacturing and material engineering. ELSEVIER. (2207-2214)2014.

[2] Sreenivasalu reddy et al, "influence of cutting parameters on the hole diameter accuracy and the thrust force in the drilling of Aluminium alloy" IJIRSET. (6442-6450)2013.

[3] Arun syan,Rr,etal,"Parameter optimization of machining process on AL6082 alloy by taguchi method" international journal for technological research in Engineering. (2927-2932)2016.

[4] Lewlyn lr Rodrigues, "process parameter optimization in GRPF drilling through integration of taguchi and response surface methodology" Research gate. (7-15)2012.

[5] Senthil Babur t al, "Influence of various parameter on the hole quality in drilling of Al based composites." ARPN journal of engineering and applied science". (14482-14490)2016.