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Investigation on Influence of drilling parameters on Thrust force and Torque - Based on Design of Experiments

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Abstract— Drilling, a hole producing process is especially important because it accounts for a large portion of overall machining operations. Amongst all machining operations, drilling using twist drill is the most commonly applied method for generating holes for riveting and fastening structural assemblies. It is well known that the drill point geometry has a significant effect of the thrust force of a twist drill. The present research initiative in an attempt to investigate the relative significance of the drilling parameters such as point angle, spindle speed, feed rate and drill diameter on the thrust force and torque using Taguchi design method. Drilling operations have been conducted over a wide a range of cutting condition. Spindle speed varied in the range 350 rpm to 750 rpm in 3steps, Feed rate varied from 0.3 to 0.6mm /rev in 3 steps. HSS-R (DIN 338) two flutes uncoated conventional twist drills of 3 different diameters (8, 10 and 12mm) with 118^0 point and 45^0 helix angles. Drill bits tool geometry altered by tool&cutter grinder and obtained 110^0, 100^0 point angles without changing helix angle. Drilling was performed on rectangular bars of Alluminium 7075, 2014 and 6061 alloy work pieces of size 300mmx50mmx10mm with dry condition as per taguchi L_{27} orthogonal array. A kistler (type 9272), four components (F_X,F_Y,F_Z and M_Z) dynamometer was used and the signal was processed by a type 5070 multichannel signal amplifier unit (Kistler 5070 type) was used to record the thrust force and torque. Finally, confirmation test has been carried to compare the predicted values with the experimental values to confirm its influence of parameters on thrust force and torque.

Index Terms — Drilling, Alluminium alloys, Thrust Force, Torque, Taguchi-Design of Experiments

1 INTRODUCTION

THIS drilling performance measured includes thrust force and torque. Each of these measures is affected by various factors and variables such as the tool and work piece materials properties, the tool geometry, the cutting conditions, cutting fluid and machine tool. Also this chapter separately reviews what has been done in the past in the area of drilling parameters to optimize thrust force and torque.

1.1 LITERATURE REVIEW

J.S. Strenkowski etal [1] developed an Eulerian thermo-viscoplastic finite element model that has been developed for oblique cutting, which is based on representing the drill point geometry as a series of oblique sections. S. Madhavan etal [2] studied experimentally the delamination factor of drilled Glass Fabric – Epoxy /Rigid polyurethane foam sandwich hybrid composite has been investigated and the results are given using the Design of Experiments. R. Vimal Sam Singh etal [3] developed a Fuzzy rule based model for predicting thrust force and torque in drilling of GFRP composites. P. V. Gopal Krishna etal [4] investigated a friction drilling which is a nontraditional hole making process in which a conical rotating tool is applied to penetrate into workpiece and create the hole in a single step, without generating chips. M. Pirtini, I. Lazoglu [5] reveals that, a new mathematical model based on the mechanics and dynamics of the drilling process is developed for the prediction of cutting forces and hole quality. M Sundeep etal [6] investigated experimentally on drilling behavior of AISI 316 and attempt made to optimize the process parameters using L9 Orthogonal array design of experiment of Taguchi methodology. B.Suresh kumar etal [7] reveals the conclusions after conducting experiments on drilling operation by using CNC and conventional machines on titanium alloy; the conventional drilling machine produces higher vibrations than CNC machines. M.Vijaya Kumar etal[8], presented in their work optimization of drilling parameters of AMMC for minimizing the thrust force, temperature and surface roughness using Desirable-Fuzzy approach. Naseer Ahmed [9] presented a 3D thermo mechanically coupled finite element model of drilling process of steel 2080 to study the influence of cutting parameter on thrust force and torque. Experiments are performed to validate the results from simulations. Vaishak N L etal [10] presented their efforts to understand the influence of important machining parameters like thrust force and torque that are produced during drilling of Granite particulate Reinforced Epoxy Composite. S.Prakash etal [11] conducted experimental study drilling operation towards medium density fibre (MDF) board. K. Anand Babu etal [12] examined the influence of drilling parameters on Aluminium Metal Matrix Composite (Al7075/10% - SiCp). Rajiv Chaudhary etal [13], reviewed on Experimental Investigations

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and Taguchi Analysis with Drilling Operation, They focused on the investigations made on drilling using Taguchi Techniques. Hari Singh etal [14], drilling experiments were conducted using L27 orthogonal array, to optimize the process parameters considering weighted output response characteristics using grey relational analysis. Norfadzlan Yusup etal [15] reviewed on current area of research (during 2007-2011) on conventional and non conventional (Evolutionary) techniques of machining processes.

1.2 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.

2. EXPERIMENTAL PROCEDURE

At present, aluminium is used in the aviation industry everywhere in the world. These are used for manufacturing various components of spaceship equipment: brackets, fixtures, chassis, covers and casing for many tools and devices. Engineers and manufacturers never cease to study the properties of aluminium, developing more and more new alloys for construction of aircraft and spaceships. 2xxx, 6xxx, and 7xxx series alloys are widely used in automotive and aviation industries.

In this study, the experiments were carried out on a radial drilling machine (Make: Siddapura Machine Tools, Gujarat, INDIA) to perform different size of holes on Al 2014,6061 and7075 alloy work pieces. The drill tools used were HSS-R (DIN 338) twist drills made by Bosch and commercially available with diameters of 8, 10 and 12mm with 118^0 point angle and 45^0 helix angle. Drill bits tool geometry altered by tool&cutter grinder. A Kistler type 9272, Kistler Instrumente AG, CH8408, Winterthur, Switzerland, four components (F_X, F_Y, F_Z and M_Z) dynamometer was used to measure thrust force and torque and the signal was processed to the computer by a type 5070 multichannel signal amplifier (shown in fig.1).

fig.1 Kistler dynamometer type 9272 (Kistler Instrumente AG, CH8408, Winterthur, Switzerland), Multichannel signal amplifier (kistler type 5070) and radial drilling machine (Make: Siddapura Machine Tools, Gujarat, INDIA)

2.1 METHODOLOGY

The orthogonal array forms the basis for the experimental analysis in the Taguchi method. The selection of orthogonal array is concerned with the total degree of freedom of process parameters. Total degree of freedom (DOF) associated with five parameters is equal to 10 (5X2). The degree of freedom for the orthogonal array should be greater than or at least equal to that of the process parameters. There by, a L_{27} orthogonal array having degree of freedom equal to (27-1) 26 has been considered, which is used to optimize the cutting parameters for burr size, surface roughness and circularity deviation using the S/N ratio and ANOVA for machining of Al 2014, 6061and7075 alloys and predicted results were nearer to the experimental results. Although similar to design of experiment (DOE), the taguchi design only conducts the balanced (orthogonal) experimental combinations, which makes the taguchi design even more effective than a fractional factorial design. By taguchi techniques, industries are able to greatly reduce product development cycle time for design and production, therefore reducing costs and increasing profit. Also neural network technique has been applied to compare the predicted values with the experimental values and compared the error between experimental values. Finally, confirmation test have been carried out to compare the predicted values with the experimental values confirm its effectiveness in the analysis of thrust force and torque. The machining parameters and their levels are given in table1. Plan of experiments based on Taguchi orthogonal array and observed responses shown in table 2.

Table1: Factors and their levels

Levels	FACTORS				
	Material	Spindle Speed (rpm)	Feed Rate (mm/min)	Drill dia (mm)	Point Angle (Deg)
	A	B	C	D	E
1	Al 7075	465	0.18	8	100
2	Al 2014	795	0.18	10	110
3	Al 6061	795	0.26	12	118

Table 2: Plan of experiments based on Taguchi orthogonal array and observed responses

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RUNS	TAGUCHI RESPONSE DESIGN TABLE							S/N Ratio	Means
	Chosen Parameters					Measured Responses			
	A	B	C	D	E	Thrust Force(N)	Torque(Nm)		
						Fz	Mz		
1	Al 7075	465	0.18	8	100	241.698	1.101	-44.6883	121.400
2	Al 7075	465	0.18	8	110	135.241	0.557	-39.6119	67.899
3	Al 7075	465	0.18	8	118	395.956	0.197	-48.9426	198.077
4	Al 7075	795	0.18	10	100	202.091	0.545	-43.1007	101.318
5	Al 7075	795	0.18	10	110	208.196	0.052	-43.3891	104.124
6	Al 7075	795	0.18	10	118	265.494	0.474	-45.4708	132.984
7	Al 7075	795	0.26	12	100	316.636	1.791	-47.0010	159.214
8	Al 7075	795	0.26	12	110	186.740	2.573	-42.4153	94.657
9	Al 7075	795	0.26	12	118	52.2614	0.371	-31.3538	26.316
10	Al 2014	465	0.18	12	100	366.636	0.762	-48.2744	183.699
11	Al 2014	465	0.18	12	110	253.922	0.506	-45.0837	127.214
12	Al 2014	465	0.18	12	118	325.299	1.126	-47.2284	163.212
13	Al 2014	795	0.26	8	100	195.071	1.182	-42.7937	98.126
14	Al 2014	795	0.26	8	110	139.481	0.577	-39.8801	70.029
15	Al 2014	795	0.26	8	118	250.944	0.297	-44.9812	125.620
16	Al 2014	795	0.18	10	100	154.009	0.708	-40.7407	77.358
17	Al 2014	795	0.18	10	110	303.598	0.827	-46.6387	152.213
18	Al 2014	795	0.18	10	118	351.005	0.966	-47.8960	175.986
19	Al 6061	465	0.26	10	100	146.533	0.556	-40.3085	73.544
20	Al 6061	465	0.26	10	110	189.764	0.576	-42.5540	95.170
21	Al 6061	465	0.26	10	118	254.899	1.158	-45.1172	128.029
22	Al 6061	795	0.18	12	100	192.097	0.772	-42.6602	96.435
23	Al 6061	795	0.18	12	110	114.560	2.301	-38.1721	58.431
24	Al 6061	795	0.18	12	118	76.0933	2.051	-34.6198	39.072
25	Al 6061	795	0.18	8	100	99.781	0.060	-36.9707	49.921
26	Al 6061	795	0.18	8	110	69.384	0.486	-33.8181	34.935
27	Al 6061	795	0.18	8	118	20.139	0.348	-23.0717	10.242

3. RESULTS AND DISCUSSIONS

In the Taguchi method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value (Standard Deviation) for the output characteristic. Therefore, the S/N ratio to the mean to the S.D. S/N ratio used to measure the quality characteristic deviating from the desired value. The S/N ratio is defined as $\eta = -10 \log (M.S.D)$, Where M.S.D is the mean square deviation for the output characteristic.

Table 2 shows the experimental results for observed responses. The S/N ratio table for observed responses is shown in Table 3a&3b.

Table 3(a). Response Table for Signal to Noise Ratios
Smaller is better

Level	Material	Spindle Speed	Feed Rate	Drill Diameter	Point Angle
1	-44.84	-44.64	-41.68	-39.41	-42.95
2	-37.48	-40.27	-41.82	-43.91	-41.28
3	-42.88	-41.87	-40.97		
Delta	7.36	4.37	0.14	4.50	1.98
Rank	1	3	5	2	4

Table 3(b). Response Table for Means

Level	Material	Spindle Speed	Feed Rate	Drill Diameter	Point Angle
1	130.38	128.69	105.25	86.25	106.78
2	65.09	89.28	96.75	115.64	89.41
3	111.78	105.36	111.06		
Delta	65.30	39.42	8.51	29.39	21.65
Rank	1	2	5	3	4

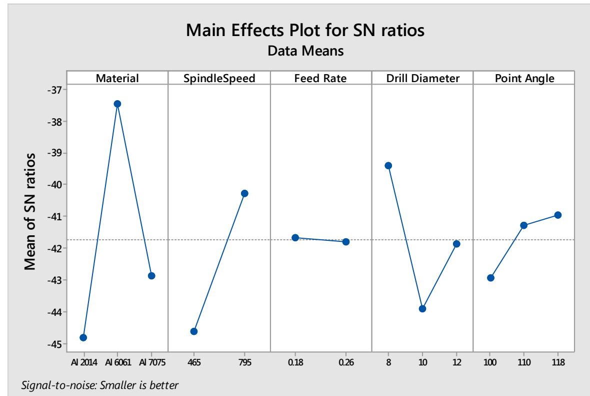

fig.2 Main effects plor forS/N Ratios

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Material	2	0.1019	0.05097	0.14	0.873
SpindleSpeed	1	0.2017	0.20167	0.54	0.471
Feed Rate	1	0.3466	0.34656	0.93	0.347
Drill Diameter	2	3.6106	1.80529	4.85	0.021
Point Angle	2	0.1244	0.06221	0.17	0.847
Error	18	6.6938	0.37188		
Total	26	11.0789			

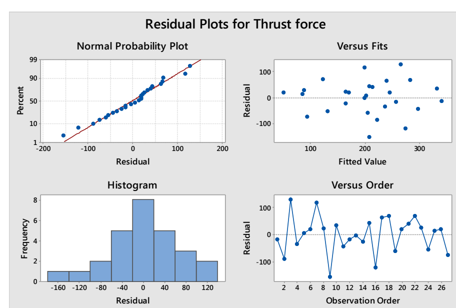

fig3.residual plot for thrust force

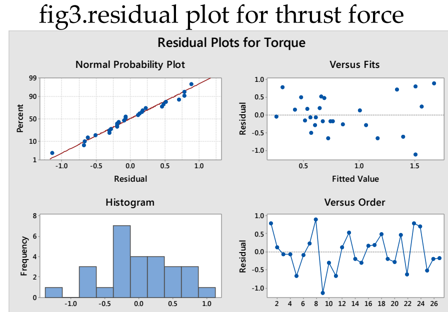

fig.4 residual plot for torque

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4 Conclusion

The machining characteristics of Al alloys have been studied. The primary machining characteristics such as thrust force and torque were studied for drilling process. From results, the combination of parameters having the values of 495rpm, 0.26 mm/rev,8mm and118^0 are obtained for spindle speed, feed rate drill diameter, and point angle respectively for optimizing thrust force and torque.

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