EXPERIMENTAL INVESTIGATION AND OPTIMIZATION OF SURFACE ROUGHNESS IN DRILLING OPERATION OF ALUMINIUM ALLOY BY TAGUCHI AND ANOVA

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ABSTRACT

Drilling operation play an important role in the manufacturing industry. Drilling operation performed by conventional method or unconventional method both methods have it own value as per requirements. Drilling operation widely used in the aerospace, aircraft and automotive industries and modern metal cutting methods are improved.
In this Experimental study, focused on the optimization of drilling parameters using the Taguchi method to obtain minimum surface roughness (Ra) and hole diameter. A number of drilling experiments were conducted using the L9 orthogonal array on conventional drilling machine. The experiments were performed on AI 7075 alloy block using High Speed steel (HSS) twist drills under dry cutting conditions. The Experimental results were recorded and analyzed with the help of MINITAB17. Analysis of variance (ANOVA) was employed to determine the most significant control factors affecting the surface roughness and hole diameter. The spindle speed, feed rate and Lubrication were selected as control factors. The main and interaction effect of the input variables on the predicted responses are investigated. The predicted values and measured values are fairly close.

Keyword: - *Taguchi, Al7075, ANOVA, Orthogonal Array, Surface Roughness etc.*

1. INTRODUCTION

Drilling is one of the most commonly used machining processes to produce holes in many industrial components. The surface quality of hole is the main problem associated with drilling of machined components. Drilling is a major and common of hole making process. Drilling is the cutting process of using a drill bit in a drill to cut or enlarge holes in solid materials, such as wood or metal. 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, such as reaming, tapping and boring. The cutting process in which a hole is originated or enlarged by means of a multipoint, fluted, end cutting tool. As the drill is rotated and advanced into the work piece, material is removed in the form of chips that move along the fluted shank of the drill. Figure 1 shows the drilling operation on to the work piece.
Due to poor surface roughness of drilled hole cost of component is increased in deburring and edge finishing operation. Precision component cost is increased as much high of 30% to the cost of part. Surface roughness is a combination of finer irregularities over machined surfaces due to inherent action of the production process surface roughness has received great influence on functioning of machined parts which significantly improves creep life, fatigue strength and corrosion resistance.
In the aero space industry depending on the application hole quality is very important and response process variable outputs. at interest are the important and quality characteristics of holes in this experimental investigation process are analyzed to spindle speed, feed rate and different lubrication are as input parameter.

Fig -1 drilling operation on to the work piece

2. MATERIALS AND METHOD USED

2.1 Material and Machine

Aluminium Alloy has best properties is that it is light in weight with a density one third of steel, 2.700 kg/m^3. The low density of aluminium accounts for it being lightweight but this does not affect its strength. Aluminium alloys commonly have tensile strengths of between 70 and 700 MPa. Aluminium alloys are alloys in which aluminium (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc.

Table -1 Chemical composition of Aluminium alloys

Alloy	Si	Fe	Cu	Mn	Mg
%	0.40	0.50	1.2- 2.0	0.30	2.1-2.9
Alloy	Cr	Zn	Ti	Rem	
%	0.18-0.28	5.1-6.1	0.20	Al	

Fig -2: Drilled specimen after drilling

2.2 Cutting Tool

Drilling is a versatile machining process used to produce holes with the use of multi-edged cutting edges by removing material from the surface of a work-piece. Drilling is a complicated process and many factors affect the quality of the machined surface. In this study, drilling is performed on Al 7075 bar which are difficult to machine alloy. The drilling operation is performed on a semi automatic drilling machine that produces hole at a spindle speed, feed in presence of cutting fluid. Cutting fluid is used to lubricate the machined surface and too reduce heat from the tool and the work-piece. Therefore, three cutting parameters i.e. spindle speed, feed and cutting fluid, used in drilling operation.

2.3 Cutting Fluids:

In this experiment three types of cutting fluid were used.

- Diesel Oil
- Vegetable oils
- Water Soluble Cutting Fluid

Diesel Oil

The density of petroleum diesel is about **0.832 kg/L** (6.943 lb/US gal), about 11.6% more than ethanol-free petrol (gasoline), which has a density of about **0.745 kg/L** (6.217 lb/US gal).

Vegetable oils

A vegetable oil is a triglyceride extracted from a plant The term "vegetable oil" can be narrowly defined as referring only to plant oils that are liquid at room temperature, or broadly defined without regard to a substance's state of matter at a given temperature, For this reason, vegetable oils that are solid at room temperature are sometimes called vegetable fats. In contrast to these triglycerides, vegetable waxes lack glycerin in their structure. Although many plant parts may yield oil, in commercial practice, oil is extracted primarily from seeds.

The density of the oils varies with each type and temperature. The range is from **0.91**to **0.93 g/cm^3** between the temperatures of 15°C and 25°C Comparing to water, whose density is **1.00 g/ml**, cooking oil is less dense.

Water Soluble Cutting Fluid

Commercial name: Lactuca 3000 IN

Chemical Name: Paraffinic long chain hydrocarbons

Synonyms: Hydrocarbons

C.A.S. No.: Not Applicable

Product application: Soluble Cutting Oil

Company name: TOTAL OIL INDIA PVT. LTD

Fig -3: water soluble cutting fluid

2.4 DOE and orthogonal array

In this work, the Taguchi method was used to design the experimental parameters. This Taguchi method can reduce the number of experiments required to obtain necessary data for optimization with the use of DoE. Therefore, DoE using DoE and Taguchi approach has become a much more attractive tool for those who attempt the optimization of

any system. A total of three parameters namely Spindle speed, feed and lubrication were chosen for the controlling factor, and each parameter is designed to have three levels, namely small, medium, and large, denoted by A, B and C, as shown in the Table 2.
Mean while, a L9 Orthogonal array table is used to conduct the experiments. This array table has 3 column and 9 rows as shown in Table 3. Therefore only 9 experiments were needed to study the entire drilling parameter space using the L9 orthogonal array. To obtain a more accurate result, each combination of experiments was repeated three times.

2.5 Machining parameters and their levels

Table -2: Machining Parameters and their Levels

Symbol	Control Factor	Unit	Level 1	Level 2	Level 3
A	Spindle speed	RPM	60	160	180
B	Feed	Rev/min	0.045	0.045	0.045
C	Lubricant		VG	DI	CF

2.6 Orthogonal Array by Design Expert Software

Table -3: Taguchi's L9 OA

S.No.	Spindle speed (RPM)	Feed (mm/rev)	Lubricant
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

2.7 Taguchi Method

Taguchi method is one of the simplest and effective approaches for parameter design and experimental planning (Fisher, 1925). In this method, the term 'signal' represents the desirable value (mean) for the output characteristic and the term 'noise' represents the undesirable value i.e. standard deviation (S.D.) for the output characteristic. Therefore, the S/N ratio is the ratio of the mean to the S.D. There are three types of S/N ratio depending on type of characteristics-the lower-the-better, the higher-the-better, and the nominal-the-better. The Taguchi method is summarized in the following steps.

1. Identification and evaluation of quality characteristics and process parameters.
2. Identification of number of levels for the process parameters and possible interactions between the process parameters.
3. Assignment of process parameters to the selected appropriate orthogonal array.
4. Conduction of experiments based on the arrangement of the orthogonal array.
5. Calculation of S/N ratio.
6. Analyze the experimental results using the S/N ratio and ANOVA.
7. Selection of the optimal levels of process parameters.
8. Verification of the optimal process parameters through the confirmation experiment.

2.8 Analysis of the signal-to-noise (S/N) ratio

The mean S/N ratio graph for surface roughness is shown in chart1 and 2. The S/N ratio corresponds to the smaller Variance of the output characteristics around the desired value.

Table -4: L9 Machining Orthogonal array with the values of response variables

S.No.	Spindle speed (RPM)	Feed (mm/rev)	Lubricant	Surface Roughness	S/N Ratio
1	60	0.045	VG	0.56	5.03624
2	60	0.086	DI	0.63	4.01319
3	60	0.142	CF	0.85	1.41162
4	160	0.045	DI	0.77	2.27019
5	160	0.086	CF	0.81	1.83030
6	160	0.142	VG	0.60	4.43697
7	180	0.045	CF	0.69	3.22302
8	180	0.086	VG	0.84	1.51441
9	180	0.142	DI	0.71	2.97483

Table -5: Response Table for Signal to Noise Ratios

Level	Spindle Speed	Feed	Lubrication
1	3.478	3.510	3.663
2	2.846	2.453	2.155
3	2.571	2.941	3.086
Level	0.916	1.057	1.508
Rank	3	2	1

Table -6: Response Table for Means

Level	Spindle Speed	Feed	Lubrication
1	0.6800	0.6733	0.6667
2	0.7267	0.7600	0.7833
3	0.7467	0.7200	0.7033
Level	0.0667	0.0867	0.1167
Rank	3	2	1

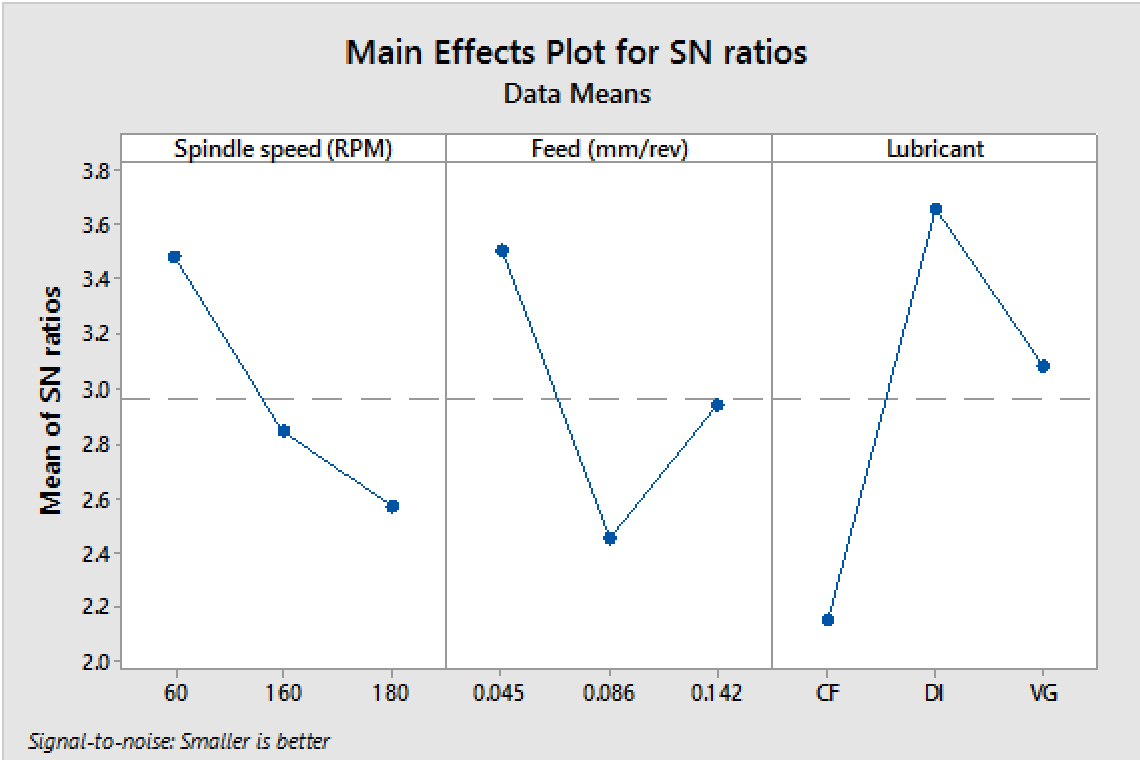

Chart -1: Main effect plot for SN ratio

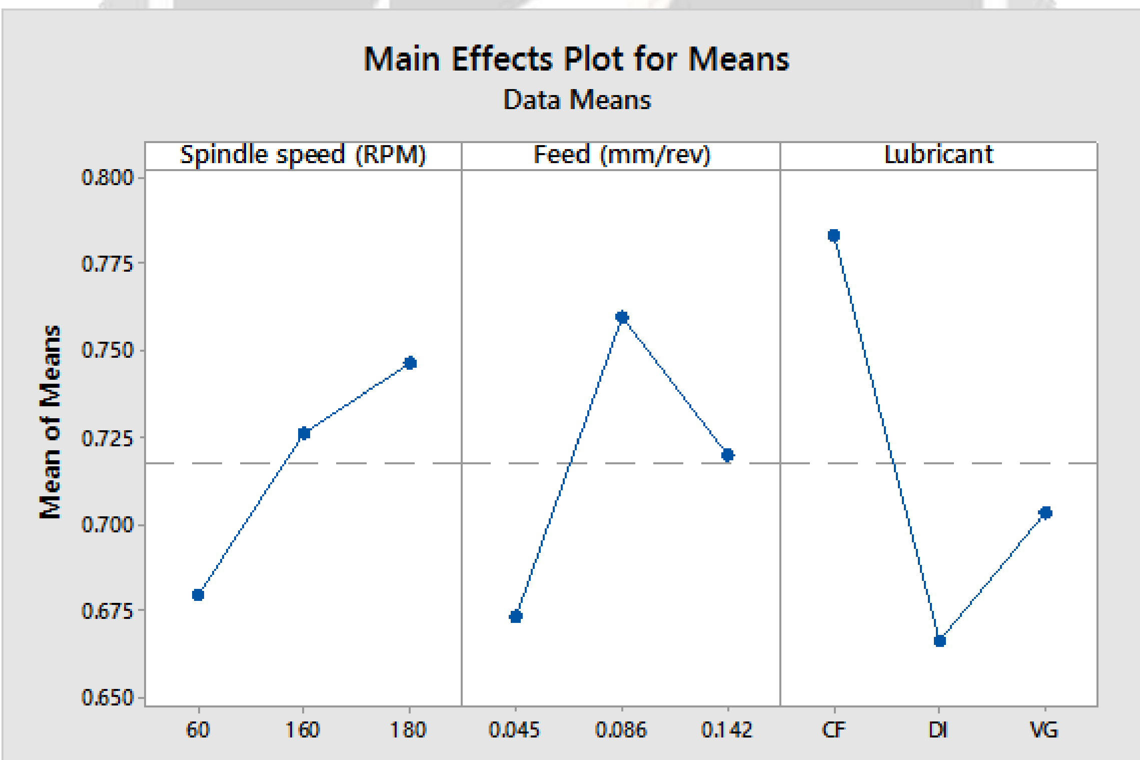

Chart -2: Main effects plot for SN ratios

For surface roughness of a drilled hole smaller is better so the optimized parameters are A3B2C1. From the above selected parameters for better surface roughness spindle speed= 180 RPM, feed = 0.086 and lubricant = CF

2.9 Analysis of variance (ANOVA)

Table -7 Results of the analysis of variance.

Source	DF	Adj.SS	Adj.MS	F-Value	P-Value	% Contribution
Spindle Speed	2	4.326	0.6632	0.18	0.849	36.94
Feed	2	3.680	0.8398	0.23	0.816	31.43
Lubrication	2	2.472	1.736	0.47	0.682	21.11
Error	2	1.232	3.716			10.52
Total	8	11.710				100.00

2.10 Residual Plots for Surface Roughness

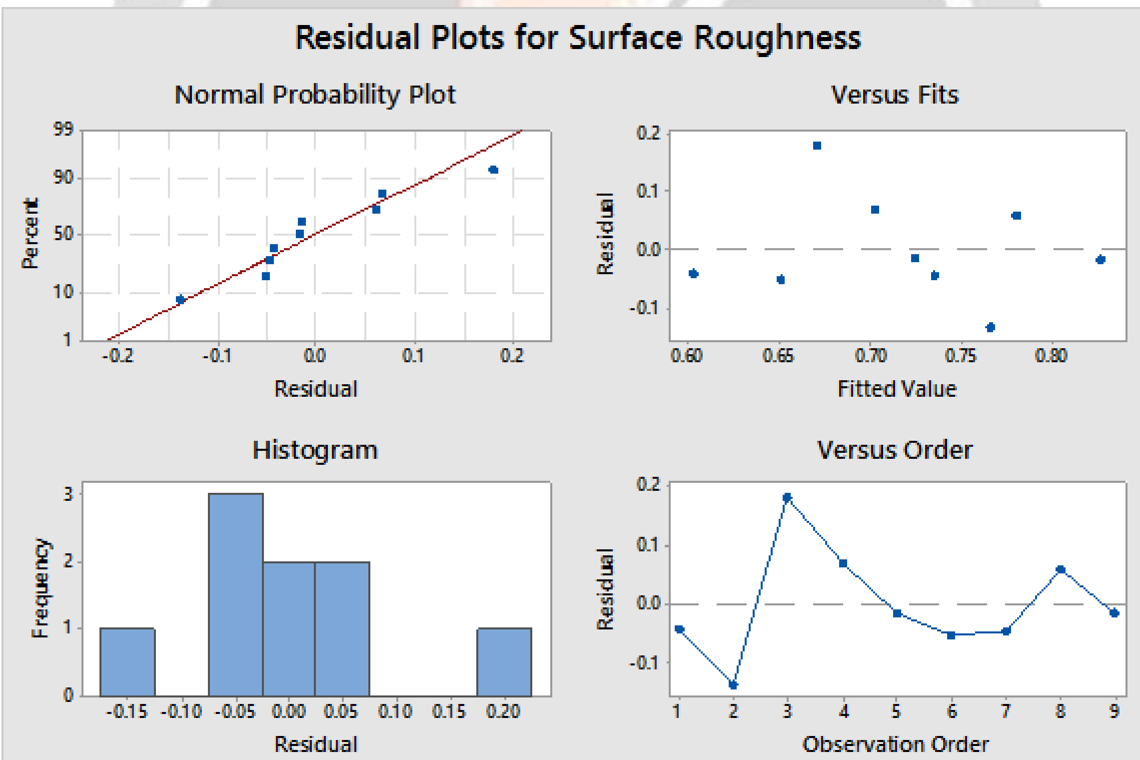

Chart -3: Residual plots for surface roughness

The residual plot of S/N ratios is shown in the above chart. This layout is useful to determine whether the model meets the assumptions of the analysis. The residual plots in the graph and the interpretation of each residual plot are:
a. Normal probability plot helps in detecting non-normality. An approximately straight line indicates that the residuals are normally distributed.

The above Normal probability plot indicates that the data are normally distributed and the variables are influencing the response. Outliers do not exist in the data, as the standardized residues are between -2 and 2.
b. The plot of residual versus the fitted values helps in detecting non constant variance, missing higher-order terms and the outliers. The residuals should be scattered randomly around zero.
The above residuals versus fitted values plot indicate a constant variance as well as absence of the outliers in the data.
c. The plot of histogram of the residuals helps in detecting multiple peaks, outliers, and non-normality. The histogram should be approximately symmetric and bell-shaped.
The above plot of histogram of the residuals points towards the presence of multiple peaks and also shows that the histogram is approximately symmetric and bell-shaped.
d. The plot of residuals versus order helps in detecting the time-dependence of residuals. The residuals should exhibit no clear pattern.
The above Residuals versus order plot indicate towards the random pattern of the residuals.

3. CONCLUSIONS

The experimental study has focused an application of the Taguchi method for the optimization of process parameters of drilling operations. As discussed earlier, the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for the optimization of the cutting parameters. Except hole-depth, cutting parameters such as spindle speed, feed, and lubricant mainly influenced the surface roughness in drilling of Al7075 bars. The optimal combination of drilling parameters and their levels for the minimum surface roughness of the drilling process are A3B2C1 (i.e. spindle speed- 180 RPM, feed-0.086 mm/rev and lubricant- CF). The percentage contributions of spindle speed, feed and lubricant are 36.94%, 31.43% and 21.11% respectively. Hence, significant improvements in surface roughness can be obtained using this approach. Finally, it can be a very useful technique for use to the industries to optimize the machining performance with minimum cost and loss of time.

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