Optimization of Drill Process Parameters for Maximum Material Removal Rate using Taguchi and ANOVA

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Abstract— An objective of this Experimental work was to optimize and analyzed process parameters namely point angle (deg), spindle speed (RPM) and feed (mm/Rev) in drilling operation of mild steel. In this work, experiments were carried out as per the Taguchi experimental design and an L9 orthogonal array was applied to study the influence of various combinations of process parameters for MRR. ANOVA (Analysis of variance) test was conducted to determine the percentage of contribution for each process parameters on drilling. The results indicate that feed is the most significant factor and point angle is the second most significant factor for Material removal rate. This work is useful for selection optimized values of various controllable process parameters that do not only maximize the MRR but also reduce the delimitation and improve the MRR.

Keywords—Drilling, DOE, Taguchi, ANOVA, Array, Mild Steel, MRR

1. INTRODUCTION

Drilling is widely used for machining processes to produce holes in various industrial parts. Drilling is a process of producing round holes in a solid material or enlarging existing holes with the help of multi-point cutting tools (drill bits). [1] Drilling is one of the widely used machining processes for various purposes. Nowadays it is frequently used in automotive, aircraft and aerospace and dies or mold industries, home appliances, and medical and electrical equipment industries. Thus, it needs to be cost-effective along with the assurance of the quality specifications within the experimental limit. In today's rapidly changing circumstances in manufacturing industries, applications of optimization techniques in metal cutting processes are essential for a manufacturing unit to respond efficiently to severe competitiveness and the increasing demand of the quality product in the market. Optimization methods in metal cutting processes, considered being a very important tool for continual improvement of output quality in products & processes [2]. The quality of drill depends on cutting tool geometry, workpiece materials, and input parameters.

2. LITERATURE REVIEW

Dr. Anant Guja et al. [3] in this study experiments were performed on SG500/7 plate using different twist drills under dry cutting conditions. The measured results were collected and analyzed with the help of the commercial software package MINITAB16. Analysis of variance (ANOVA) was employed to determine the most significant control factors affecting the surface roughness. The spindle speed (850, 1150, & 1440 rpm), feed rate (90,120 &135 mm/min) and tool material (HSS, Carbide and TiAlN Coated Carbide) were selected as control factors. The main and interaction effect of the input variables on the predicted responses are investigated. It is predicted that Taguchi method is a good method for optimization of various machining parameters as it reduces number of experiments. The results indicate the optimum values of the input factors and the results are conformed by a confirmatory test

S.V. alagarsamy et al. [4] the aim of this work was utilize Taguchi method to investigate the effects of drilling parameters such as cutting speed, feed and depth of cut on surface roughness and material removal rate in drilling of Aluminium alloy 7075 using HSS spiral drill. The Taguchi method, a powerful tool to design optimization for quality, is used to find optimal cutting parameters. Orthogonal arrays, the signal- to- noise ratio, the analysis of variance are employed to analyze the effect of drilling parameters on the quality of drilled holes. A series of experiments based on L16 orthogonal array are conducted using CNC vertical machining centre. The experiment results are collected and analyzed using statistical software Minitab16. Analyses of variances are employed to determine the most significant control factors affecting the surface roughness and material removal rate. ANOVA has shown that the depth of cut has significant role to play in producing higher material removal rate and cutting speed has significant role to play for producing lower surface roughness.

Vinod Kumar Vankanti et al. [5] objective of the present work is to optimize process parameters namely, cutting speed, feed, point angle and chisel edge width in drilling of glass fiber reinforced polymer (GFRP) composites. In this work, experiments were carried out as per the Taguchi experimental design and an L9 orthogonal array was used to study the influence of various combinations of process parameters on hole quality. Analysis of variance (ANOVA) test was conducted to determine the significance of each process parameter on drilling. The results indicate that feed rate is the most significant factor influencing the thrust force followed by speed, chisel edge width and point angle; cutting speed is the most significant factor affecting the torque, speed and the circularity of the hole followed by feed, chisel edge width and point angle. This work is useful in selecting optimum values of various process parameters that would not only minimize the thrust force and torque but also reduce the delimitation and improve the quality of the drilled hole

Ashish Tripathi et al. [6] the measurement of torque and thrust in drilling enable to find the amplitude of vibration produced that will decide the type of setup needed for the work. The objective of this research paper is to find thrust and torque in mild steel and aluminum 6061 and to find optimal values of drilling parameters so that minimum value of torque and thrust is obtained. After finding the values of thrust and torque in mild steel and aluminum6061 the comparison of values for both the materials has been presented. The lower value of thrust and torque will result into higher tool life and lower vibration in machine tool structure.

3. MATERIALS AND METHOD

3.1. Work Piece Material

Work piece material used for experiment was mild steel Table 1 shows the chemical composition of mild steel.

Table: 1 Chemical Composition of Mild Steel

Element	Composition (wt %)
C	0.16
Al	0.07
Si	0.168
Mn	0.18
P	0.025
Cu	0.09
Fe	Balance

Figure: 1. Mild Steel work piece after Drilling

3.2. Drill bits Material

High speed steel drill bits was used for drilling and every drill bit point angle was different i.e. 75, 118 and 130 deg.

Figure: 2. Different point angle HSS Drill Bit

3.3. Selection of Process Parameters

In this experiment machining process parameters like point angle (deg), Spindle Speed (rpm) and Feed (mm/rev) of the drill were considered. As per Taguchi's design of experiments for three parameters and three levels L9 Taguchi orthogonal array was selected. The number of factors and their corresponding levels are shown in Table 2.

Table: 2 Machining Parameters and Levels

Process Parameters	**Level**		
	1	**2**	**3**
Point Angle (deg)	75	118	130
Spindle Speed (rpm)	80	160	270
Feed (mm/rev)	0.45	0.86	1.42

4. METHODOLOGY

5.1. Taguchi Method

Taguchi approach was firstly introduced by Dr. Genichi Taguchi. Taguchi approach has three stage system design, parameters design, and tolerance design. Taguchi approach is a statically approach to improve the product quality and increases the production. A specially designed orthogonal array of Taguchi was used in this work to investigate the effects of the entire machining parameters through the small number of experiments and it takes less time for the experimental investigations.[7]**Smaller the better:** this is used where smaller value is desired.

S/N Ratio = $-10\log\frac{1}{n}\sum_{i=1}^{n} yi^2$ ……………. (1)

Where y = observed response value and n = number of replications

Nominal the best: this is used where the nominal or target value and variation about that value is minimum.

S/N Ratio = $-10\log\frac{\mu^2}{\sigma^2}$ ……………………. (2)

Where σ = mean and μ= variance

Higher the better: this is used where the larger value is required.

S/N Ratio = $-10\log\frac{1}{n}\sum_{i=1}^{n}\frac{1}{yi^2}$ ………………… (3)

5.2. ANOVA (Analysis of Variance)

ANOVA is a statistical tool used to test differences between two or more means. It may seem odd that the technique is called "Analysis of Variance" rather than "Analysis of Means" The ANOVA is obtained by dividing the measured the sum of the squared deviations from the total mean S/N ratio into contributions by each of the control factors and the errors.[8] ANOVA identify the percentage of contribution of controlled process parameters.

Table: 3. Experimental Table with S/N Ratio

Sr. no	Point Angle	Spindle Speed	Feed	MRR	S/N Ratio
1	75	80	0.45	8.182	18.257
2	75	160	0.86	6.000	15.56303
3	75	270	1.42	11.250	21.02305
4	118	80	0.86	8.824	18.91285
5	118	160	1.42	10.000	20
6	118	270	0.45	10.714	20.59926
7	130	80	1.42	9.000	19.08485
8	130	160	0.45	13.125	22.36199
9	130	270	0.86	6.818	16.67337

5. RESULT AND ANALYSIS

Minitab17 was used has been used for analysis of the experiment. Minitab17 software analysis the experimental data and then provides the calculated results of signal-to-noise ratio. The objective of the present work was to maximize the MRR in drilling process optimization. The equations are an exception to the prescribed specifications of this template. The effect of different process parameters on MRR is calculated and plotted as the controllable process parameters change one level to another level. The average value of S/N ratios has been calculated to find out the effects of different parameters and as well as their levels. The use of both ANOVA technique and S/N ratio approach makes it easy to analyze the results and hence, make it fast to reach on the conclusion. Table III shows the experimental results for material removal rate and corresponding S/N ratios.

5.1. Analysis of Signal to Noise Ratio

Larger-the-best performance characteristic was selected to obtain material removal rate.

Table: 4. Response Table for S/N Ratio (MRR)

Level	Point Angle	Spindle Speed	Feed
1	18.28	18.75	20.41
2	19.84	19.31	17.05
3	19.37	19.43	20.04
Level	1.56	0.68	3.36
Rank	2	3	1

Table: 5. Response Table for Mean

Level	Point Angle	Spindle Speed	Feed

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From the table IV &V and figure 3 & figure 4 that feed and point angle after that spindle speed play a important role for MRR, Point Angle = 118 deg, Spindle Speed = 270 RPM and Feed = 0.45 mm/rev

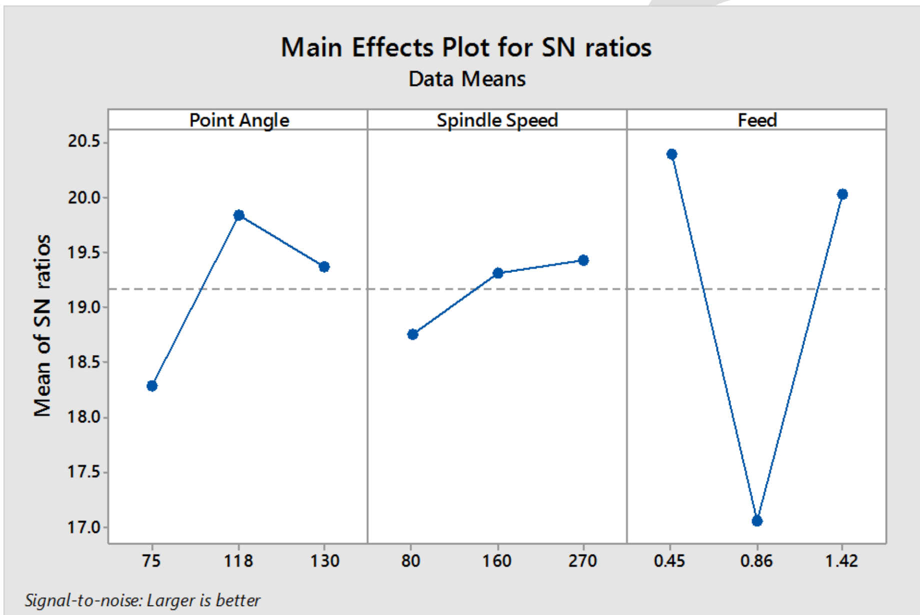

Figure: 3. Main Effect Plot for S/N Ratio of MRR

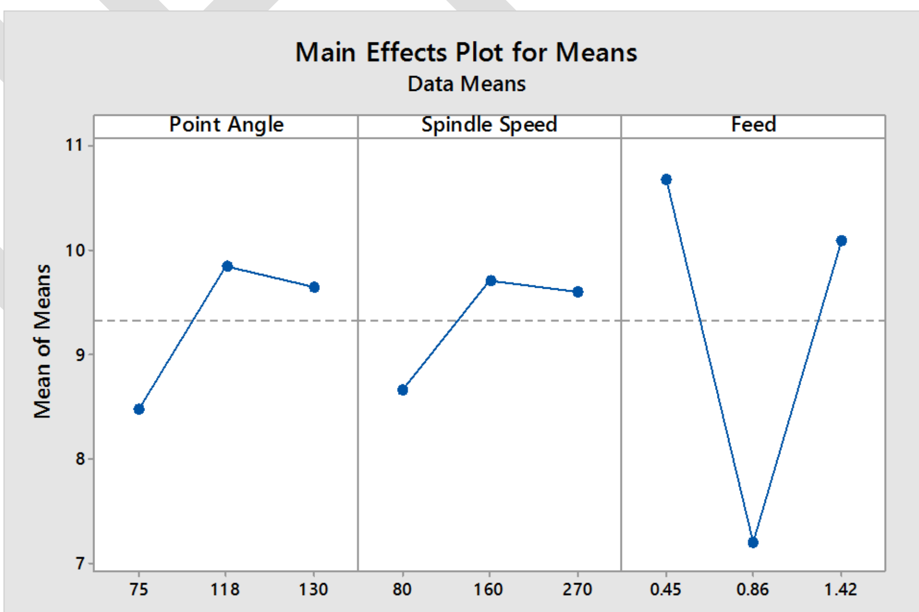

Figure: 4. Main effect Plot for Means

5.2. Analysis of Variance (ANOVA)

Minitab 17 was used to investigate the process parameters. ANOVA define the percentage of contribution for each process parameters.

Table: 6. ANOVA Result for MRR

Source	DF	SS	MS	F	P	%CON
Point Angle	2	8.282	1.6412	0.24	0.807	22.07
Spindle Speed	2	4.951	0.9757	0.14	0.876	13.19
Feed	2	20.552	10.2762	1.49	0.401	54.76
Error	2	3.749	6.8744			9.99
Total	8	37.534				100.00

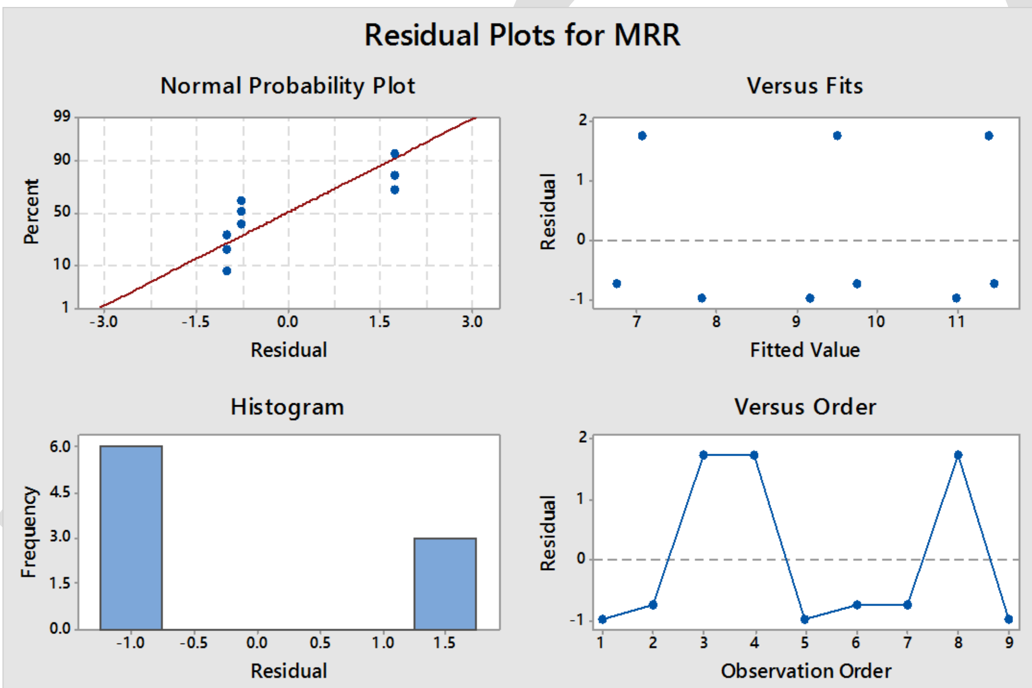

Figure: 5. Residual Plots for MRR

6. CONCLUSION

The optimize process parameters in the drilling of mild steel for optimized MRR are Point Angle 118, Spindle Speed 270 RPM and feed 0.45 mm/rev. ANOVA clearly identify that Feed is 54.76 %, point Angle 22.07 % and spindle speed 13.19 % contribute to maximum material removal rate

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