NOVATEUR PUBLICATIONS
INTERNATIONAL JOURNAL OF INNOVATIONS IN ENGINEERING RESEARCH AND TECHNOLOGY [IJIERT]
VOLUME 1, ISSUE 1 NOV-2014

Optimization of process parameters in drilling of EN 31 steel using Taguchi Method

Adikesavulu.R
PG student, Dept. of mechanical engg, MITS, Madanapalle, Chittoor (D)
* r.adikesavulu@gmail.com
Sreenivasulu. Bathina
Assistant professor, Dept. of mechanical engg, MITS, Madanapalle, Chittoor (D)
*sreenivasulub@mits.ac.in
Sreenivasulu. Bezwada
Assistant professor, Dept. of mechanical engg, MITS, Madanapalle, Chittoor (D)
* sreenivasulubejawada@mits.ac.in

Abstract

Drilling is the fundamental operation of making a cylindrical hole in metal cutting industry. Thrust force and torque has a major parameter which influence on the tool life and machining economics. If thrust force and torque increases tool life will be decreases, it is necessary to drill a hole at optimum thrust force and torque as it is not possible to cut a hole at zero thrust force and torque. The objective of the present work is to optimize process parameters to be specific cutting speed, feed, and point angle of cutting edge in drilling of EN31 steels. Experimentation were completed according to the Taguchi trial outline and L27 orthogonal array be utilized to study the control of different combinations of process parameter on the hole quality. Analysis of variance (ANOVA) statistical method is also used to determine the importance of every process parameter on drilling.

Keywords: optimization, drilling, dynamometer, thrust force, torque.

Introduction

Drilling is one of the manufacturing operations to make the holes by rotating a wedge shaped cutting tool called drill bit. The production of holes in components is the major material removal process in metal cutting industry.

Under the various estimations, drilling process is occupying 75% in metal cutting processes. Commonly, drilling is a preliminary operation to reaming, boring and grinding where ultimate finishing and sizing happen. The most commonly used drill is the twist drill. In addition to the familiar two flute twist drill there are more than a few other types in use, such as flat drills, drills with three or four flutes, core, shell and spade drills. The chips should leave through the flutes to the exterior of the tool [1].

In the earlier studies they did optimization of process parameters during the drilling of glass fiber reinforced polymer composite material and to find the significance of each process parameter used ANOVA. In the existing work, the tests were conduct by the Taguchi and ANOVA analysis and also generate the regression models by using MINITAB 15 statistical analysis software [2].

Palanikumara and Paulo Davim [3] investigated the control of cutting parameters namely critical speed, fiber course angle, deepness of metal cut and give feed rate on tool flank wear as well as the results specify that cutting speed cover a improved pressure on tool edge show off track by feed rate. Taguchi proposed that three step approach, they are system design, the parameter design and the tolerance design will be carried out the engineering optimization of process [4].

Design of experiments theory is explains huge number of changeable with a little number of conduct tests by means of Taguchi method and reduces the quantity of experimental arrangements to be there studied.

Moreover, the ending drawn from little degree tests be applicable over the total trials section lengths by the control factors also their settings [5]. However, Taguchi has modified their use by provide tabularized sets of typical orthogonal arrays and corresponding linear graphs to fit specific projects [6]. Phillip J. Ross. [7] To explain clearly graphs and results of the analysis of variance method in Taguchi techniques for quality engineering. The conducted investigational outcomes be changed into a signal-to noise (S/N) ratio. It makes utilize of the S/N proportion as an estimate of quality characteristics dissimilar from or nearing to the desired standards. The outcome exposed that the spindle speed is the main contributing process parameter for the variation in thrust force and drill diameter for torque. The phenomenon of delamination throughout drilling was identified and examined by Hocheng and Tsao [8]. They developed a mathematical representation to expect the critical thrust force using various drill bits. Khashaba et al. [9] studied the consequence of machining parameters in the drilling of GFR/epoxy composites and built-up a model to envisage the critical thrust force during drilling. Mohan et al. [10] cutting process parameters in drilling of glass fiber reinforced composite (GFRC) material optimized and found that speed and size of drill are major control factors in cutting thrust than the model thickness and the feed rate. Kilickap [11] study the power of cutting parameters, such as cutting speed, feed rate and point angle on delimitation formed when drilling a GFRP composite and concluded that feed rate and cutting speed are the mainly powerful factor on the delimitation, correspondingly. A significant amount of research was carried out to find the influence of machining parameters on the delaminating of composite laminates using Taguchi and analysis of variance techniques [12–15].

The objective of the present work is to enhance the process parameters in drilling of EN 31 steel with Taguchi method furthermore study the importance of each of process parameter along with analysis of variance (ANOVA). The present work, MINITAB 16 is statistical analysis software was utilized for the design and study of experiments to perform the Taguchi and analysis of variance. In this work, the process parameters are optimized in drilling of EN 31steel utilized Taguchi design of experimental technique and the results are analyzed with analysis of variance technique to identify the percentage contribution of each parameter on thrust force, torque and surface finish of the hole.

Methodology

Taguchi method

Taguchi developed a particular design of orthogonal arrays to study the whole parameter space with a little amount of experiments. Then transformed the experimental results to taken with a signal-to-noise(S/N) ratio. It utilizes the signal to noise percentage to estimate of quality characteristics dissimilar from or nearing to the preferred values. S/N ratios are three types of excellence characteristics, i.e. the smaller is the better, the higher is the better, and the nominal is the finest. The formula utilized to designed for analyze S/N percentage, it is shown below.

***Smaller -is-better*:**

It is utilized where the smaller value is desired. For drilling process cutting force, torque, surface roughness and power should be low for better quality; hence smaller S/N ratios are measured for these parameters.

$$\frac{S}{N} ratio(\eta) = -10\log_{10}\frac{1}{n}\sum_{i=1}^{n} y_i^2 \qquad (1)$$

Where y_i = observed response value and n = number of imitations.

Nominal-is- finest: It is utilized wherever the nominal or object value and difference about that value is smallest.

$$\frac{S}{N}ratio(\eta) = -10\log_{10}\frac{\mu^2}{\sigma^2} \quad (2)$$

Where μ = mean and σ = variance.

Higher-is-better: It is utilized where the bigger value is preferred.

$$\frac{S}{N}ratio(\eta) = -10\log_{10}\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y^2} \quad (3)$$

Where y_i = observed react value and n = quantity of imitations.

Taguchi recommended a standard methodology for optimizing any process parameters, the steps involved in Taguchi are

- Determination of the excellence quality to be optimized.
- Identification of the smash factors and test conditions.
- Identification of control variables and their option levels.
- Designing the matrix testing in addition to significant the information analysis procedure.
- Conducting the matrix test.
- Analyzing the information furthermore determining the best possible levels of control variables.
- Predicting the recital by these levels.[6]

ANOVA

ANOVA is a statistical method for influential the degree of dissimilarity or similarity between two or more collections of information. It is focused around the correlation of the normal estimation of a typical segment. ANOVA is not a difficult process along with many mathematical beauty related with it. Analysis of variance is a statistically based, objective resolution making tool used for identify any divergence in average performance of collections of items tested. The resolution, moderately than utilizing pure judgment, receive variant into account. [7]

The sum of squares equation may be written as,

$$SS_T = SS_A + SS_B + SS_{A\times B} + SS_e$$

Where SS_T = sum of squares due to total variation.

The total variation is,

$$SS_T = \left[\sum_{i=1}^{N} Y_i^2\right] - \frac{T^2}{N}$$

Where y_i = ith observation and N= total number of samples or observations.

The general formula for any number of levels of factor A and B is,

$$\text{Sum of squares of factor A, } SS_A = \left[\sum_{i=1}^{k_A}\left(\frac{A_i^2}{n_{A_i}}\right)\right] - \frac{T^2}{N}$$

Where k_A = number of levels for factor A and n_{A_i}= sample size under conditions A_i.

$$SS_B = \left[\sum_{i=1}^{k_B}\left(\frac{B_i^2}{n_{B_i}}\right)\right] - \frac{T^2}{N}$$

Where T= sum of all observations and = sample size under conditions B_i.
The sum of data under the i^{th} condition of the combination of factor A and B is,

$$SS_{A\times B} = \left[\sum_{i=1}^{c}\left(\frac{(A\times B)_i^2}{n_{A\times B_i}}\right)\right] - \frac{T^2}{N} - SS_A - SS_B$$

The sum of square error is,

$$SS_e = SS_T - SS_A - SS_B - SS_{A\times B}$$

Selection of process parameters

For the present analyses, the machining parameters like speed, feed and point angle cutting edge of drill to be considered. As indicated by Taguchi's outline of investigations for three parameter design and three levels L27 orthogonal array be chosen. The quality of their variables and their related levels are represented in table 1.

Table. 1Preferred variable levels for drilling

Code	Variable	Level 1	Level 2	Level 3
1	Speed (rpm)	1000	1500	2000
2	Feed (mm/rev)	0.05	0.08	0.11
3	Point angle (deg)	118	130	140

Experimental work

EN31steel is used as work piece material with the size of 100 mm diameter and 10 mm thickness. Taguchi's L27 orthogonal array was used to conduct the drilling experiments as shown in Table (3) on EN 31steel with 10 mm diameter of solid carbide drill. Chemical composition of EN 31steel is represent in Table (2) and the mechanical properties of bearing steel are density is 7.85 g/cc, tensile strength is 750 N/mm^2, yield stress is 450 N/mm^2, modulus of elasticity 215000 N/mm^{2}and also hardness is 63 HRC etc.

Table.2 chemical composition of bearing steel bar grade EN 31steel

Grade	C	Si	Mn	Cr	S	P	Fe
EN 31	0.95-1.20	0.10-0.35	0.30-0.75	1.00-1.60	0.05	0.05	Remaining

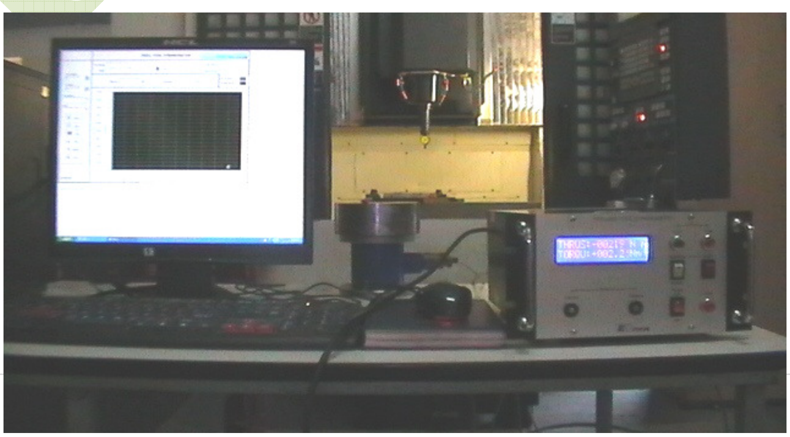

Fig.1-The Experimental setup utilized for drilling process.

Each experiment was carried out twice to minimize the experimental error. A computer numerical control (CNC) vertical machining centre (model: Makino S33 (VMC)) was used for conducting experiments. The axial thrust force and torque are measure from the instrument of Syscon make of Drilling dynamometer. The proportional charge amount produced from the dynamometer be fed to an amplifier hence produced a scale voltage output signal relative to the functional load. Thrust force and torque be always observed as well as the results were record during the experiment by means of a digital storage oscilloscope. A Pentium III framework with wave star programming was utilized to interface with the oscilloscope to pile up the thrust force and torque graphs The experimental arrangement utilized for drilling operation is shown in Fig.1. After the completion of the experimentation, surface roughness of the fine quality of drilled holes was measured by Mitutoyo make of surf test SJ-201 Talysurf surface profile meter.

Table 3-The basic Taguchi L27(3^3) orthogonal array.

.Exp.No	speed(rpm)	feed(mm/rev)	point angle(degrees)
1	1000	0.05	118
2	1000	0.05	130
3	1000	0.05	140
4	1000	0.08	118
5	1000	0.08	130
6	1000	0.08	140
7	1000	0.11	118
8	1000	0.11	130
9	1000	0.11	140
10	1500	0.05	118
11	1500	0.05	130
12	1500	0.05	140
13	1500	0.08	118
14	1500	0.08	130
15	1500	0.08	140
16	1500	0.11	118
17	1500	0.11	130
18	1500	0.11	140
19	2000	0.05	118
20	2000	0.05	130
21	2000	0.05	140
22	2000	0.08	118
23	2000	0.08	130
24	2000	0.08	140
25	2000	0.11	118
26	2000	0.11	130

27	2000	0.11	140

Results and discussions

The results of thrust force, torque and surface irregularity of every sample are analyzed. The experimental results were altered into S/N percentage using Eq. (1). The main effect for mean and S/N proportion is graphs within Figs. 2–4, respectively.

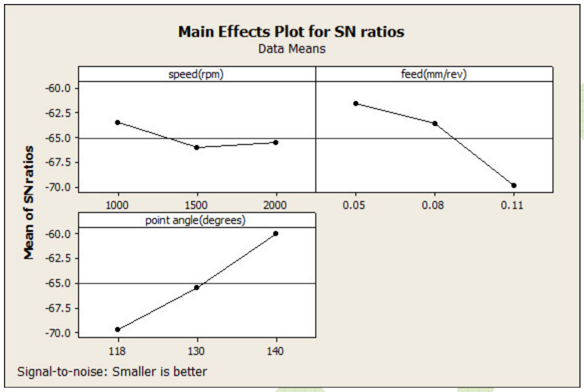

Fig .2 Most important effects plot for S/N ratio (thrust force).

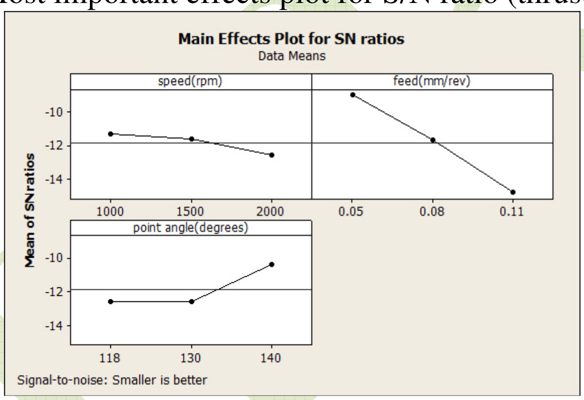

Fig .3 Most important effects plot for S/N ratio (torque)

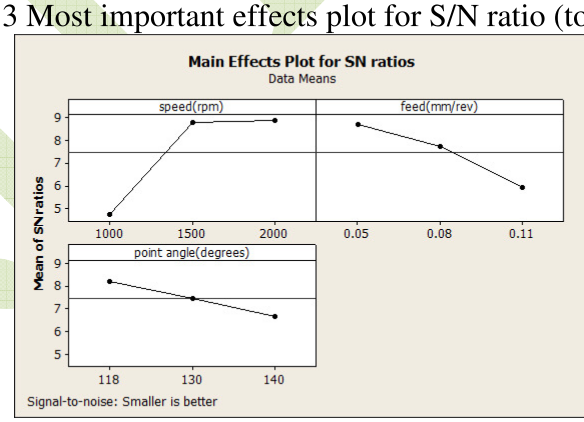

Fig.4 Most important effects plot for S/N ratio (surface roughness)

Fig. 2 shows the weight of process parameters on the thrust force. The optimum process parameters on the thrust force are obtained as speed at level 1 (1000 rpm), feed at level 1 (0.05 mm/rev) and point angle at level 3 (140^0). Fig. 3 shows the outcome of cutting parameters on the torque. The optimum process parameters on the torque are obtained as speed at level 1 (1000 rpm), feed at level 1 (0.05 mm/rev) and point angle at level 3 (140^0) and Fig. 4 show the pressure of cutting parameters on the surface unevenness. The optimum process parameters on the surface roughness are obtained as speed at level 1 (1000 rpm), feed at level 3 (0.11 mm/rev) and point angle at level 3 (140^0). The degree of importance of each parameter is considered, namely speed, feed, point angle for each response is shown in Table respectively. Table 4, it is found that feed is the main factor affecting the thrust force followed by point angle and speed. Table 5, feed and point angle are found to be most important factors affecting the torque followed by speed. It can be observed from table 6 that, speed has the greatest influence on surface roughness or surface finish followed by point angle and feed. The model adequacy checking was conducted after performing an ANOVA analysis to verify the normality postulation of the residual. Fig.5,6,7 show constant variance, normality, independence, histogram plots , common probability plots of the residuals and these figures reveal that almost all the residuals follow a straight line pattern and this agrees well with the results reported by Davidson et al. [17]. This work will be useful for industries while the selection of process parameters in the drilling of EN 31steel materials, to get better the quality of the drilled holes by reducing the thrust force and torque.

Table .4 Two-way ANOVA: thrust force(N) versus feed(mm/rev), point angle(degrees)

Source	DF	SS	MS	F	P
Feed (mm/rev)	2	25417411	12708705	28.6	0.000
Point angle (deg)	2	23566034	11783017	26.01	0.000
Interaction	4	12393028	3098257	6.84	0.002
Error	18	8153673	452982		
Total	26	69530145			

S = 673.0   R-Sq = 88.27%   R-Sq(adj) = 83.06%

Table .5 Two-way ANOVA: torque(Nm) versus feed(mm/rev), point angle(degrees)

Source	DF	SS	MS	F	P
Feed (mm/rev)	2	35.1108	17.5554	19.51	0.000
Point angle (deg)	2	7.1526	3.5763	3.98	0.037
Interaction	4	3.3636	0.8409	0.93	0.466
Error	18	16.1939	0.8997		
Total	26				

S = 0.9485   R-Sq = 73.81%   R-Sq(adj) = 62.16%

Table .6 Two-way ANOVA: Ra versus feed(mm/rev), point angle(degrees)

Source	DF	SS	MS	F	P
Feed (mm/rev)	2	0.11064	0.055320	0.45	0.646
Point angle (deg)	2	0.05958	0.029792	0.24	0.788
Interaction	4	0.05403	0.013507	0.11	0.978
Error	18	2.22008	0.123338		
Total	26	2.44433			

S = 0.3512   R-Sq = 9.17%   R-Sq(adj) = 0.00%

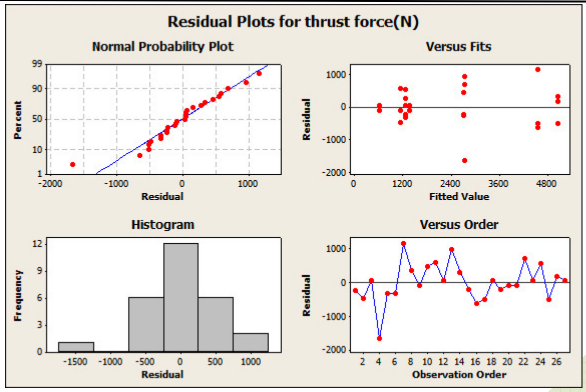

Fig.5 Residual plots for thrust force versus feed, point angle

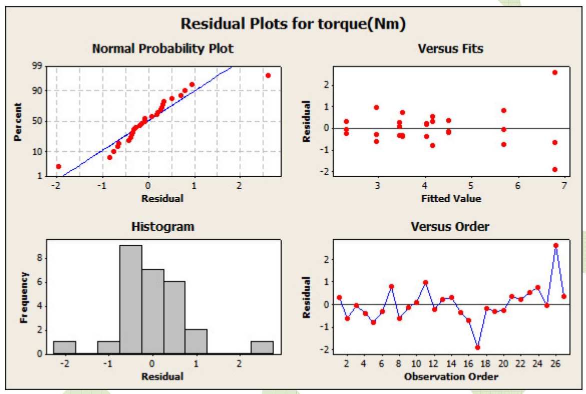

Fig .6 Residual plot for torque versus feed , point angle

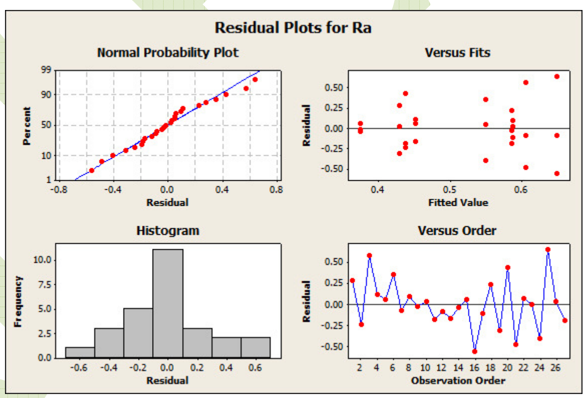

Fig .7 Residual plots for surface roughness versus feed, point angle

Conclusions

This paper presents the optimization of cutting process parameters namely, cutting speed, feed and point angle during in drilling of EN 31 steel material using the application of Taguchi and ANOVA analysis. The conclusions drawn from this work are as follows:

The optimum process parameters in the drilling of EN 31steel are:

- Speed of 1000 rpm, feed rate at 0.05 mm/rev and point angle at 140^0 for thrust force whereas for torque, speed at 1000 rpm, feed rate of 0.05 mm/rev and point angle at $140^0$are found to be optimum.

- Speed at 1000 rpm, feed rate of 0.11 mm/rev and point angle at 140^0 for surface roughness are the optimum parameters.

The ANOVA results reveal that feed rate and point angle are the most significant influencing on the thrust force, torque and surface finish.

References:

[1]. Gopal Krishna P V, Kishore K, Srihari T.Optimizatio of process parameters for a modified chisel edge HSS drill. J Mechanical and Civil Engineering 2014;Volume11,Issue 2,PP 08-15.

[2]. Vinodkumar Vankanti,venkateswarlu Ganta,Optimization of process parameter in drilling of GFRP composite using Taguchi method. J Mater Res Technol, 2014;3(1):35-41.

[3]. Palanikumara K, Paulo Davim J. Assessment of some factors influencing tool wear on the machining of glass fiber-reinforced plastics by coated cemented carbide tools. J Mater Process Technol 2009;209:511–9.

[4]. Taguchi G. Introduction to quality engineering, Asian Productivity Organization. Dearborn, MI: Distributed by American Supplier Institute Inc.; 1986.

[5]. Phadke SM. Quality engineering using robust design. Englewood Cliffs, N.J: Prentice Hall; 1989.

[6]. ASI. Taguchi methods: implementation manual. Dearborn, MI, USA: American Supplier Institute Inc. (ASI); 1989.

[7]. Phillip J. Ross . Taguchi techniques for quality engineering .Mc GRAW- Hill publishing company limited.; 1996

[8]. Hocheng H, Tsao CC. Comprehensive analysis of delamination in drilling of composite materials with various drill bits. J Mater Process Technol 2003;140:335–9.

[9]. Khashaba UA, EI-Sonbaty IA, Megahed AA. Machinability analysis in drilling of GFR/epoxy composites: Part I. Effect of machining parameters. Composites Part A: Appl Sci Manufact 2010;41:391–400.

[10]. Mohan NS, Ramachandra A, Kulkarni SM. Influence of process parameters on cutting force and torque during drilling of glass–fiber polyester reinforced composites. Compos Struct2005;71:407–13.

[11]. Kilickap E. Optimization of cutting parameters on delamination based on Taguchi method during drilling of GFRP composite. J Expert Syst Appl 2010;37:6116–22.

[12]. Bagci E, Ozcelik B. Analysis of temperature changes on the twist drill under different drilling conditions based on Taguchi method during dry drilling of Al7075-T651. J Adv Manufact Technol 2006;29:629–36.

[13]. Abrao AM, Campos Rubio JC, Faria PE, Davim JP. The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite. J Mater Des 2008;29:508–13.

[14]. Rubio JC, Abrao A, Faria P, Esteves Correia A, Davim JP. Effects of high speed in the drilling of glass fibre reinforced plastic: evolution of the delamination factor. Int J Mach Tools Manufact 2008;48:715–20.

[15]. Abrao AM, Campus Rubio J, Faria PE, Davim JP. The effect of cutting tool geometry on thrust force and delamination when drilling glass fibre reinforced plastic composite. Mater Des 2008;29:508–13.

[16]. Davidson MJ, Balasubramanian K, Tagore GRN. Surface roughness prediction of flow-formed AA6061 alloy by design of experiments. J Mater Process Technol 2008;202:41–6."

.