Analysis And Optimization of Drilling Parameters Using Taguchi Design of Experiments

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Abstract- *This research outlines the Taguchi optimization methodology, which is applied to optimize cutting parameters in drilling of Cast Iron, 150Bhn. The drilling parameters evaluated are cutting speed, feed rate, thrust, torque and work material factor. Series of experiments are conducted to relate the cutting parameters on the thrust force and torque. Orthogonal array, signal-to-noise ratio is employed to analyze the influence of these parameters on thrust force and torque during drilling. The study shows that the Taguchi method is suitable to solve the stated problem with the minimum number of trials. The main objective is to find the important factors and combination of factors that influence the machining process to achieve low thrust force and torque. The analysis of the Taguchi method indicates that the feed rate is the most significant factor affecting the thrust force, while the drill diameter contributes the most to the torque.*

Keywords- Degree of Freedom, F Value, S/N Ratio.

I. INTRODUCTION

Metal cutting operations, such as drilling, turning, and milling, are widely used in manufacturing to produce a variety of mechanical components. Hole drilling is by far the most widely used process in manufacturing. Conventional drilling with twist drill still remains one of the most economical and efficient machining processes for hole making as well as for riveting and fastening structural assemblies in the aerospace and automotive industries. Drilling operations are mainly dependent on the cutting parameters and drilling tools. The critical thrust and torque at the onset of unproductiveness play the major role, and those are correlated with the process parameters. In addition, drilling problems can result in costly production because many drilling operations are usually among the final steps in fabricating a part. Among the scientific problems in drilling, determining the thrust force and torque for any drill geometry, especially the variation of helix angle, remains an issue. Then understanding of parameter dependency on thrust force and torque can bring some strategic information to optimize the drilling operations. In drilling process, the efficiency and the quality of the finished component are heavily dependent on the process, work piece, and tool-related parameters employed while machining. Cutting speed, feed rate, and helix angle are drilling parameters that significantly affect the performance measures such as thrust force and torque. The machining parameters are usually selected based on either the experience or the proposed guidelines of the manufacturers. This selection procedure does not lead to the optimal and economically effective use of the machines and the quality of the surface generated. Sometimes, scientific methods based on Taguchi orthogonal array are used.

In statistics, the ANOVA is a collection of statistical models, and their associated procedures, in which the observed variance is partitioned into components due to different explanatory variables. Effect plots help visualize the impact of each factor combination and identify which factors are most influential. However, a statistical hypothesis test is needed in order to determine if any of these effects are significant. Analysis of variance (ANOVA) consists of simultaneous hypothesis test to determine if any of the effects are significant. Several calculations will be made for each main factor and interaction term.

The various steps used in the ANOVA are explained below:

Sum of Squares (SS): It is the total of sum of all the squared effects for each factor. It also helps in estimating the coefficient of each factor.

$$ss_{Total} = Y'Y - \frac{(\sum_{i=1}^{n} Y_i^2)^2}{n}$$

Where,
$Y'Y = \sum_{i=1}^{n} Y_i^2$ Y= response matrix
Y'= transpose of response matrix

Degrees of freedom (DF): It is the number of free units of information. It is the number of model terms, including the intercept minus one.

$$DF_{Total} = Total\ number of\ runs - 1$$

Mean Square (MS): It estimates the model variance, which is calculated by the model sum of Squares divided by model degrees of freedom.

$$MS_{Total} = \frac{SS_{Total}}{DF_{Total}}$$

F-Value: It is the test for comparing model variance with residual (error) variance. If these variances are close, the F-ratio will be close to one indicating that none of the factor is significant.

$$F - Value = \frac{SS_{Total}}{MS_{Residual}}$$

TORQUE

Formula for Torque:

M= 0.000025 KdFTFMAW [Nm]

Abbreviations for different Torque Factors:

S.N	Parameter
1	Work material factor Kd(=14000for cast iron at 150b.h.n)
2	Feed Factor FT
3	Torque factor for drill diameter FM
4	Chisel edge factor for Torque A(1.085 constant)
5	Tool wear factor W

THRUST

Formula for Thrust:

T= 0.05 Kd FF FTB W + 0.007 KddJW [N]

Abbreviations for different Thrust Factors:

S.N	Parameter
1	Work material factor Kd
2	Feed Factor FF
3	Thrust factor for drill diameter FT
4	Chisel edge factor for Thrust B(1.355 constant)
5	Tool wear factor W(=1.30 normal drilling)
6	Chisel edge factor for Thrust J(.030constant)
7	Drill diameter d

Selected levels of Parameter

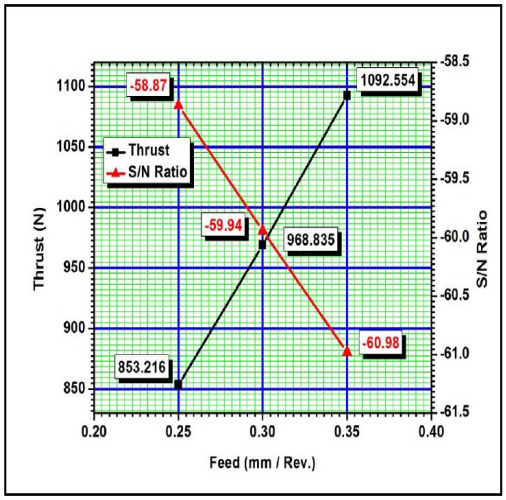
Parameter	Level1	Level 2	Level 3
Drill Diameter (mm)	1.60	2.40	3.20
Feed rate F(mm/rev)	.25	.30	.35
Cutting speed v	30	40	50

II. RESULTS AND DISCUSSION

The drilling tests were carried out using drills that cutting speeds and feed rates in different levels. In general, the thrust and torque parameters will mainly depend on the manufacturing conditions employed, such as feed, cutting speed, tool geometry, machine tool, and cutting tool rigidity. The effect of cutting parameters and the drill geometry on thrust force and torque produced was investigated.

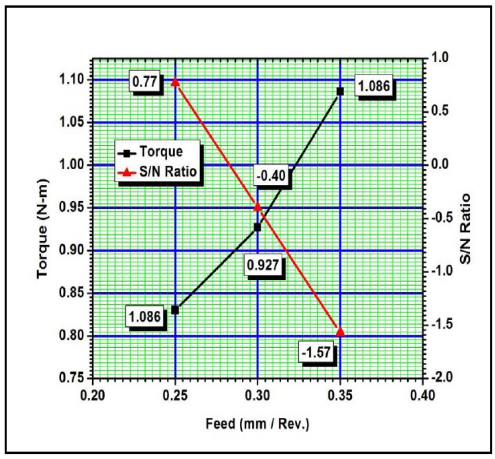
L9 orthogonal array

Exp.no	Drilldiameter (mm)	Feed (mm/rev)	Cutting speed(m/min)	Thrust (N)	Torque (N-M)
1	1.60	.25	30	603.867	.379
2	1.60	.30	40	697.480	.3380
3	1.60	.35	50	787.493	.496
4	2.40	.25	40	843.965	.788
5	2.40	.30	50	973.485	.912
6	2.40	.35	30	1098.023	1.032
7	3.20	.25	50	1111.817	1.322
8	3.20	.30	30	1235.541	1.531
9	3.20	.35	40	1392.138	1.731

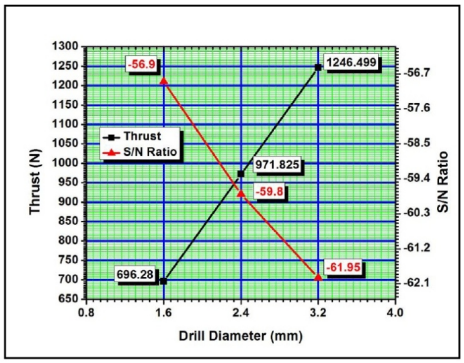


Graph showing variation of thrust and S/N ratios with feed

The above figure is a plot of variation of thrust and its S/N ratios with varying feed rate. The graph shows that thrust increases with increase in feed rate which makes a drill operation a bit rough plus increases the chance of drill bit wear and tear and bending. Larger S/N ratio occurs at minimum of the selected feed rate thereby indicating that lower level of feed rate is more suitable for drilling to be optimum.



The above figure is a plot of variation of Torque and its S/N ratios with varying feed rate. The graph shows that Torque increases with increase in feed rate from0.25mm/rev to 0.30mm/rev and rate of increase in torque is much more when feed rate increases from 0.30mm/rev to 0.35mm/rev.Excessive torque developed increase the unnecessary power requirement and may distort the workpiece. Larger S/N ratio occurs at minimum of the selected feed rates thereby confirming that lower level of feed rate is more suitable for drilling to be optimum.



Graph showing variation of thrust and S/N ratios with diameter

III.CONCLUSIONS:

In this study, statistically designed experiments based on Taguchi methods were performed using orthogonal array to analyze the thrust force and torque as response variables, respectively. The result indicates that the data are well correlated with the predicted data. Hence this technique can be very much useful for a reliable prediction of different performances. According to results, the significant factors affecting the thrust force and torque are the feed rate. It can be inferred from the interaction plots to thrust force and torque that the interaction between the parameters also has an effect on thrust force and torque. Eventually, increased drill diameter and increased feed rate increase thrust force and torque. By applying proper parameters, the responses can be controlled.

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