A Review on Optimization of Drilling Parameters Using Taguchi Methods

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Abstract— The objective of the present work is to optimize process parameter such as cutting speed, feed, point angle, chisel edge width etc. In this paper, a comprehensive and in-depth review on optimization of drilling parameters using Taguchi methods is carried out. The quality and productivity aspects are equally important in the analysis of drilling parameters. Taguchi methods are widely used for design of experiments and analysis of experimental data for optimization of processing conditions. The research contributions are classified into methodology for investigation and analysis, input processing conditions and response variables.

Keywords- Drilling, Taguchi method, Analysis of Variance, Thrust, Torque

I. INTRODUCTION

Various studies and surveys indicate that holemaking (drilling) is one of the most time-consuming metal cutting operations in the typical shop. It is estimated that 36% of all machine hours (40% of CNC) are spent performing holemaking operations, as opposed to 25% for turning and 26% for milling, producing 60% of the resultant chips. Therefore, the use of high-performance drills and reamers could significantly reduce the time required for drilling operations, and thus reduce holemaking costs. A drilling machine comes in many shapes and sizes; from small hand-held power drills to bench mounted and finally floor-mounted models. They can perform operations other than drilling, such as countersinking, counterboring, reaming, and tapping large or small holes. [1]

II. METHODOLOGY

Design of Experiments (DOE) was developed in the early 1920s by Sir Ronald Fisher at the Rothamsted Agricultural Field Research Station in London, England. His initial experiments were concerned with determining the effect of various fertilizers on different plots of land. The final condition of the crop was not only dependent on the fertilizer but also on a number of other factors (such as underlying soil condition, moisture content of the soil, etc.) of each of the respective plots. Fisher used DOE which could differentiate the effect of fertilizer and the effect of other factors. Since then DOE has been widely accepted and applied in biological and agricultural fields. A number of successful applications of DOE have been reported by many US and European manufacturers over the last fifteen years or so. [2]

Experiments are performed today in many manufacturing organizations to increase our understanding and knowledge of various manufacturing processes. Experiments in manufacturing companies are often conducted in a series of trials or tests which produce quantifiable outcomes. For continuous improvement in product/process quality, it is fundamental to understand the process behaviour, the amount of variability and its impact on processes. In an engineering environment, experiments are often conducted to explore, estimate or confirm. Exploration refers to understanding the data from the process. Estimation refers to determining the effects of process variables or factors on the output performance characteristic. Confirmation implies verifying the predicted results obtained from the experiment. [3]

III. ANALYSIS OF VARIANCE (ANOVA)

The Analysis Of Variance (ANOVA) is a powerful and common statistical procedure in the social sciences. It is the application to identify the effect of individual factors [10]. In statistics, 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. In its simplest form ANOVA gives a statistical test of whether the means of several groups are all equal, and therefore generalizes. [4]

IV. TAGUCHI APPROACH

Basically, experimental design methods were developed originally Fisher. However, classical experimental design methods are too complex and not easy to use. Furthermore, a large number of experiments have to be carried out when the number of the process parameters increases, to solve this problem, the Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. The experimental results are then transformed into a signal – to noise (S/N) ratio to measure the quality characteristics deviating from the desired values. Usually, there are three categories of quality characteristics in the analysis of the S/N ratio, i.e., the lower – better, the higher – better, and the nominal – better. The S/N ratio for each level of process parameter is compared based on the S/N analysis. Regardless of the category of the quality characteristic, a greater S/N ratio corresponds to better quality characteristics. Therefore, the optimal level of the process.
parameters is the level with the greatest S/N ratio. Furthermore, a statistically significant with the S/N and ANOVA analyses, the optimal combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. [5]

There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems. The formulae for signal to noise ratio are designed so that an experimenter can always select the largest factor level setting to optimize the quality characteristic of an experiment. Therefore a method of calculating the Signal-To-Noise ratio we had gone for quality characteristic. [6]. They are

- Smaller-The-Better,
- Larger-The-Better,
- Nominal-The-Best.

V. CLASSIFICATION OF RESEARCH WORKS

The contributions by various researchers on optimization of drilling parameters using Taguchi methods can be classified. The research works are classified under the following:

1. The methodology for performing the investigation
2. The method for analysis
3. The input processing conditions/parameters for the simulation/modeling/experimentation
4. The outputs of the process or response variables

In the study conducted by Turgay Kiyak and Gurcan Samtas, the effect of drilling parameters on surface roughness and thrust force were investigated. A number of drilling experiments were conducted using the L16 orthogonal array on a CNC vertical machining centre. The experiments were performed on AISI 316 stainless steel blocks using uncoated and coated M35 HSS twist drills under dry cutting conditions. Analysis of variance (ANOVA) was employed to determine the most significant control factors affecting the surface roughness and thrust force. The cutting tool, cutting speed and feed rate were selected as control factors. After the sixteen experimental trials, it was found that the cutting tool was the most significant factor on the surface roughness and that the feed rate was the most significant factor on the thrust force. The results of the confirmation experiments showed that the Taguchi method was notably successful in the optimisation of drilling parameters for better surface roughness and thrust force. [7]

![Fig. 1 Effects of control factors on surface roughness.](image-url)
As a result of experimental trials performed using the Taguchi OA, it was found that the cutting tool was the most significant factor affecting the surface roughness with a percentage contribution of 39.14%, and that the feed rate was the most significant factor affecting the thrust force with a percentage contribution of 82.77%.

In another similar work by Yogendra Tyagi, and Vedansh Chaturvedi, described the Taguchi technique for optimization of surface roughness in drilling process. In this the drilling of mild steel with the help of CNC drilling machine operation with Tool use high speed steel by applying Taguchi methodology has been reported. The Taguchi method is applied to formulate the experimental layout to ascertain the Element of impact each optimum process parameters for CNC drilling machining with drilling operation of mild steel. A L9 array, taguchi method and analysis of variance (ANOVA) are used to formulate the procedure tried on the change of parameter layout. The available material study in focuses optimization of CNC Drilling machine process parameters to provide good surface finish as well as high material removal rate (MRR). The surface finishing and material removal rate have been identified us quality attribute and are assumed to be directly related to productivity. The selection of optimal machining parameters i.e., spindle speed, depth of cut and feed rate) for drilling machine operations was investigated in order to minimize the surface roughness and to maximize the material removal rate [8]

Table 1: Design scheme of experiment of Parameters and levels

<table>
<thead>
<tr>
<th>Control parameters</th>
<th>Level</th>
<th>Observed Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Minimum</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Spindle Speed (rpm)</td>
<td>1000</td>
<td>1500</td>
</tr>
<tr>
<td>Feed Rate (mm/min.)</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Depth of cut (mm)</td>
<td>0.03</td>
<td>0.05</td>
</tr>
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</table>

This paper has discussed the feasibility of machining Mild Steel by drilling machine with a HSS Tool. We can conclude that, the Spindle Speed of drilling machine Tool mainly affects the Surface Roughness. The Feed Rate largely affects the Material Removal Rate.

In another work by A. Navanth, T. Kartihkeya Sharma, described the Taguchi technique for optimization of surface roughness in drilling process. The experiments were performed on Al 2014 alloy block using HSS 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 and hole.
diameter. The cutting tool, spindle speed and feed rate 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. [9]

![Fig. 10 Plots of main effects for means, S/N ratio, and interaction data means of Roughness](image1)

![Fig. 3 Plots of main effects for means, S/N ratios, and interaction data means for of Hole diameter](image2)

It was identified that a spindle speed of 300 rpm, point angle & Helix angle of 1300/200 and a feed rate of 0.15 mm/rev is the optimal combination of drilling parameters that produced a high value of s/n ratios of hole roughness. And also identified that a spindle speed of 200 rpm, point angle & Helix angle of 900/150 and a feed rate of 0.36 mm/rev is the optimal combination of drilling parameters that produced a high value of s/n ratios of Hole Diameter.

In the work done by Vinod Kumar Vankanti and Venkateswarlu Ganta the effects of drilling on glass fibre reinforced plastic were investigated. The objective of the experiment 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 [10].

<table>
<thead>
<tr>
<th>Process parameter</th>
<th>Sum of squares(SSi)</th>
<th>% Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>3.7222</td>
<td>25.85</td>
</tr>
<tr>
<td>Feed</td>
<td>5.5556</td>
<td>38.61</td>
</tr>
<tr>
<td>Point angle</td>
<td>2.7222</td>
<td>18.91</td>
</tr>
<tr>
<td>Chisel edge width</td>
<td>2.3889</td>
<td>16.62</td>
</tr>
</tbody>
</table>

Table 2 Contribution of process parameter for thrust force

<table>
<thead>
<tr>
<th>Process parameter</th>
<th>Sum of squares (SSi)</th>
<th>% Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>0.0001722</td>
<td>53.44</td>
</tr>
<tr>
<td>Feed</td>
<td>0.000722</td>
<td>22.42</td>
</tr>
<tr>
<td>Point angle</td>
<td>0.000389</td>
<td>12.07</td>
</tr>
<tr>
<td>Chisel edge width</td>
<td>0.000389</td>
<td>12.07</td>
</tr>
</tbody>
</table>

Table 3 Contribution of process parameter for thrust
From Table 2, it is found that feed is the major factor affecting the thrust force followed by speed, chisel edge width and point angle. In Table 3, speed and feed are found to be the most significant factors affecting the torque followed by point angle and chisel edge width.

CONCLUSION

The following conclusions can be drawn from this in-depth literature review on drilling processes:

- Taguchi method has been used to determine the main effects, significant factors and optimum machining conditions to obtain better performance characteristics.
- The multiple performance characteristics such as tool life, cutting force, surface roughness and the overall productivity can be improved by useful tool of Taguchi method.
- Surface roughness is determined by several factors which include cutting parameters such as cutting speed, feed, depth of cut, Tool geometry, The material of the cutting tool, Machining condition etc.
- In drilling of GFRP the ANOVA results reveal that feed rate and speed are the most significant influencing on the thrust force, torque and surface finish.

REFERENCES

[8] Turgay Kivak,Gurcan, Samtas,Adem Cicek,Taguchi method based optimization of drilling parameters in drilling of AISI 316 steel with PVD monolayer and multi layer coated HSS drillsReceived in revised form 17 February 2012