A Review on Mild Steel Drilling Process Parameters for Quality Enhancement

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Abstract: The objective of this study is to illustrate procedure adopted in Taguchi method for sheet metal processing on a drilling machine. The orthogonal array, signal-to-noise ratio and the analysis of variance are employed to study the performance characteristics in drilling operation. In this analysis, three factors namely speed; feed and depth of cut are considered. This paper deals with optimization of Drilling machine process parameter to provide good surface finish as well as high surface removal rate used as quality attributes and are considered to be directly related to productivity. Taguchi method is a statistical approach to optimize the process parameters and improve the quality of components that are to be manufactured.

Keyword: Drilling machine, Surface roughness, Material Removal Rate, Taguchi method, ANNOVA

1] INTRODUCTION

Taguchi’s parameter design offers a systematic approach for optimization of various parameters with regard to performance quality and cost. The quality and cost is one of the prime requirements of customers for machined parts productivity is also necessary to fulfill the customers demand. For this purpose quality of a product and productivity should be high and cost should be low. Design optimization for quality was carried out and single to noise ratio and analysis of variance (ANOVA) were employed using experiment result to confirm effectiveness of this approach. The signal to noise ratio in Taguchi methodology was used to find optimal parameter for material removal rate and surface roughness in drilling operation based experimental results done on mild steel work piece and high speed steel tool. The personnel industry as well as in research and development is required maintain surface roughness and MRR. Mild steel and is extensive used us a main engineering material in various industry such as air craft and aerospace industry impact of drilling parameter such as speed in rpm. Feed rate mm/min depth of cut in mm. the drilling tool diameter is constant. The tool angle is fixed 118º .the Taguchi optimization methodologies to optimize the drilling parameter in drilling machining age hardened mild steel and tool is high speed steel. Authors analyzed the data using ANOVA with the help of commercial software package minitab-15. A series of experiment based on the Taguchi L9 orthogonal array is utilized for experimental planning for CNC drilling machining.[1]

2] LITERATURE REVIEW:

Tygi et al. [2] used Taguchi Method and investigate the effect of machining parameter i.e., spindal speed, feed rate, depth of cut on surface roughness (SR) of Drilling machine tool mainly affect the SR. Koklu [3] investigated the effect of the mechanical properties of mild steel and feed rate, cutting speed And drill diameter on burr height and surface roughness of drilling, using the Taguchi method. The result of statically analysis shows that cutting speed and feed rate minimize significantly both the height of exit burrs and the surface roughness. To sun [4] worked on statically analysis of process parameter for surface roughness in drilling of mild steel and alloy steel metal matrix composite. The experimental study are conducted under varying feed rate, spindle speed drill type, point angle of drill, and heat treatment. The determined significant factor was the feed rate and tool type.
Kilickap et al. [5] focused on the influence of machining parameter i.e. cutting speed, feed rate and cutting environment on the surface roughness in a drilling of mild steel and alloy steel. Thiren G. Pokar, Prof. V. D. Patel [6] used grey based taguchi method to determine the optimum micro drilling process parameters. B. Shivaprakash, K. Chandrasekaran, C. Parthasarathy, M. Samuel [7] have tried to optimize the drilling process involving metal matrix composites (MMC) in order to minimize the damage done to it during the process by using taguchi and grey rational analysis. The input parameter is spindle speed, depth of cut and feed rate whereas the output parameters are MRR and surface roughness.

Taguchi method is a powerful tool for the design of high-quality systems. It provides a simple, efficient and systematic approach to optimize the designs for performance, quality, and cost. The methodology is valuable when the design parameters are qualitative and discrete. Taguchi parameter design can optimize the performance characteristics through the settings of the design parameters and reduce the sensitivity of the system performance to sources of variation. In recent years, the rapid growth of interest in the Taguchi method has led to numerous applications of the method in a worldwide range of industries and countries.

Basically, experimental design methods were developed originally by 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 [8][9] 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.

There are 3 Signal-to-Noise ratios [10][11] 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. They are:

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

3.1 General steps involved in the Taguchi Method are as follows:

1. Define the process objective, or more specifically, a target value for a performance measure of the process. This may be a flow rate, temperature, etc. The target of a process may also be a minimum or maximum; for example, the goal may be to maximize the output flow rate. The deviation in the performance characteristic from the target value is used to define the loss function for the process.
2. Determine the design parameters affecting the process. Parameters are variables within the process that affect the performance measure such as temperatures, pressures, etc. that can be easily controlled. The number of levels that the parameters should be varied at must be specified. For example, a temperature might be varied to a low and high value of 40 °C and 80 °C. Increasing the number of levels to vary a parameter at increases the number of experiments to be conducted.
3. Create orthogonal arrays for the parameter design indicating the number of and conditions for each experiment. The selection of orthogonal arrays is based on the number of parameters and the levels of variation for each parameter, and will be expounded below.
4. Conduct the experiments indicated in the completed array to collect data on the effect on the performance measure.
5. Complete data analysis to determine the effect of the different parameters on the performance measure.[12]

3.2 Signal to Noise Ratio (S/N Ratio) Consideration:

Taguchi found out empirically that S/N ratios give the (near) optimal combination of the factor levels, where the variance is minimum, while keeping the mean close to the target value, without using any kind of model. For that purpose, the experimental results should be transformed into the S/N ratios. There are three categories of the S/N ratio
(a) Smaller-the-better : \( S/N (\eta) = -10 \log_{10} \{ (\text{Ri}) \} \) 
\( i=1,2,3,.. \)  
(b) Larger-the-better : \( S/N (\eta) = -10 \log_{10} \{ (\text{Ri}) \} \) 
\( i=1,2,3,..r \)  
(c) Nominal-the-best : \( S/N (\eta) = 10 \log \left\{ \frac{\text{Ri}}{\text{S2}} \right\} \)  

Where Ri is value of surface roughness for the i th trial in r number of tests. The levels of each design parameters have been identified, analysis of the influence of machining parameters on response parameters.

**INPUTS**
- Cutting speed (m/min) 
- Feed rate (mm/rev) 
- Point angle (degrees) 

**METHODOLOGY**
- L\(_2\) Orthogonal array 
- ANOVA 
- Surface roughness (Ra)

**OUTPUTS**

Figure 3. Flow diagram of methodology for analysis of surface roughness (Ra) in drilling [13]

3.3 Analysis of Variance (ANOVA) :  
Analysis of variance (ANOVA) is a collection of statistical models, and their associated procedures, in which the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are all equal, and therefore generalizes t-test to more than two groups. ANOVA is used in the analysis of comparative experiments, those in which only the difference in outcomes is of interest. The statistical significance of the experiment is determined by a ratio of two variances. This ratio is independent of several possible alterations to the experimental observations: Adding a constant to all observations does not alter significance. Multiplying all observations by a constant does not alter significance. So ANOVA statistical significance results are independent of constant bias and scaling errors as well as the units used in expressing observations.

3.4 High Speed Steel  
One of our tools for the drilling operation will be the high speed steel. High speed steel (HSS)are used for making drilling tools, we used tool diameter 10mm in the drilling machine and point angle is118º This property allows HSS to drilling faster than high carbon steel, hence the name high speed steel. At room temperature, in their generally recommended heat treatment, HSS grades generally display high hardness. The composition of high speed steel are carbon (0.6%to0.75%) tungsten (14%to20%),Chromium (3%to5%),vanadium (1%to1.5%), Cobalt (5%to10%) and remaining is iron.

4] MACHINING PROCESS:
Calculating mass of each plate by the high precision digital balance meter before machining operation and before machine process for particular tool path of using various levels of spindle speed, feed rate and, depth of cut. in Experiments were performed using Manually operate drilling machine. After that calculating mass of each work piece plate again by the digital balance meter. The MRR values were measured three times of each specimen and then, the material removal rate Values were average. The Ra values also measured three times on each specimen and the surface roughness (Ra) is measured with a mitutoyo surftest SJ-201 series 178 portable surface roughness tester instrument. Machining experiments for determining the optimal machining parameter were carried out by setting of spindle speed in the range of 1000-2000 rpm, feed in the range of 0.5-1.5 mm/min, depth of cut in the range of 3-7 mm and
Essential parameter of the experiment are given in table1.[1]

Table 1: Drilling machining condition

<table>
<thead>
<tr>
<th>Work Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Work piece</td>
<td>Mild steel, Rectangular shape</td>
</tr>
<tr>
<td>Spindle Speed/Feed</td>
<td>1000 to 3000 rpm</td>
</tr>
<tr>
<td>Depth of Cut</td>
<td>0.5 to 0.15 mm/min, 3 to 7 mm</td>
</tr>
</tbody>
</table>

5) DESIGN CONSIDERATIONS:

The experimental layout for the machining parameters using the L9 orthogonal array (OA) and Signal to noise ratio is done. The machine was used for the drilling operation in this study. The surface roughness are two essential part of a product in any drilling machining operation the theoretical surface roughness is generally dependent on many parameters such as the tool geometry, tool material and work piece material. This array having a three control parameters and three levels as shown in table2. This method, more essentials all of the observed values are calculated based on ‘the Higher the better’ and ‘the smaller the better’. In the present study spindle speed (N, rpm) Feed rate (f, mm/min) and depth of cut (D, mm) have been selected as design factor. while other parameter have been assumed to be constant over the Experimental domain This Experiment focuses the observed values of SR were set to maximum, intermediate and minimum respectively. Each experimental trial was performed with three simple replications at each set value. Next, Signal to noise ratio is used to optimize the observed values.

Table 2: Design scheme of experimenters of parameter and level [1]

<table>
<thead>
<tr>
<th>Control Parameter</th>
<th>Level</th>
<th>Observed Value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>Minimum</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Intermediate</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Maximum</td>
</tr>
<tr>
<td>Spindle Speed (rpm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feed rate (mm/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depth of Cut (mm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surface Roughness (Ra)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Material Removal rate</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: L9 table and observed values [1]

<table>
<thead>
<tr>
<th>No of Trail</th>
<th>Spindal Speed (rpm)</th>
<th>Feed rate (mm/rev)</th>
<th>Depth of cut (mm)</th>
<th>MRR (cm³/min) x 10⁻³</th>
<th>SR (Ra)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1000(1)</td>
<td>0.5(1)</td>
<td>0.5(1)</td>
<td>1.37</td>
<td>3.26</td>
</tr>
<tr>
<td>2</td>
<td>1000(1)</td>
<td>01(2)</td>
<td>01(2)</td>
<td>1.36</td>
<td>3.22</td>
</tr>
<tr>
<td>3</td>
<td>1500(2)</td>
<td>1.5(3)</td>
<td>1.5(3)</td>
<td>1.40</td>
<td>3.27</td>
</tr>
<tr>
<td>4</td>
<td>1500(2)</td>
<td>0.5(1)</td>
<td>0.5(1)</td>
<td>1.43</td>
<td>3.41</td>
</tr>
<tr>
<td>5</td>
<td>2000(3)</td>
<td>1.5(3)</td>
<td>1.5(3)</td>
<td>1.40</td>
<td>3.21</td>
</tr>
<tr>
<td>6</td>
<td>2000(3)</td>
<td>0.5(1)</td>
<td>0.5(1)</td>
<td>1.49</td>
<td>3.96</td>
</tr>
<tr>
<td>7</td>
<td>2000(3)</td>
<td>1.5(3)</td>
<td>1.5(3)</td>
<td>1.49</td>
<td>3.99</td>
</tr>
<tr>
<td>8</td>
<td>2000(3)</td>
<td>0.5(1)</td>
<td>0.5(1)</td>
<td>1.44</td>
<td>3.91</td>
</tr>
<tr>
<td>9</td>
<td>2000(3)</td>
<td>1.5(3)</td>
<td>1.5(3)</td>
<td>1.33</td>
<td>3.85</td>
</tr>
</tbody>
</table>

Table 4: Analysis of variance and F test for MMR

<table>
<thead>
<tr>
<th>Parameter (z)</th>
<th>DOF (fz)</th>
<th>Sum of Square (Sz)</th>
<th>Variance (Vz)</th>
<th>F-ratio (Fz)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2</td>
<td>0.013</td>
<td>0.0065</td>
<td>65</td>
<td>23.5</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>0.022</td>
<td>0.011</td>
<td>110”</td>
<td>39.3</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>0.020</td>
<td>0.010</td>
<td>100”</td>
<td>35.4</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>0.005</td>
<td>1.5855</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** significant parameter, * Sub significance parameter
Table 5: Analysis of variance and F test for MRR

<table>
<thead>
<tr>
<th>Parameter (z)</th>
<th>DOF (fz)</th>
<th>Sum of Square(Sz)</th>
<th>Variance (Vz)</th>
<th>F-ratio (Fz)</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>2</td>
<td>1.414</td>
<td>0.707</td>
<td>366.67*</td>
<td>51.908</td>
</tr>
<tr>
<td>F</td>
<td>2</td>
<td>0.732</td>
<td>0.366</td>
<td>174.285*</td>
<td>26.628</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>0.510</td>
<td>0.255</td>
<td>121.428*</td>
<td>18.400</td>
</tr>
<tr>
<td>E</td>
<td>20</td>
<td>0.042</td>
<td>0.002</td>
<td>51.908</td>
<td>1.048</td>
</tr>
</tbody>
</table>

Figure 1. Effects of parameters on MRR [1]

Figure 2. Effects of parameters on surface roughness [1]

6] FINDINGS FROM LITERATURE REVIEW:
The purpose of this study is to investigate the influence of cutting parameters, such as cutting speed and feed rate, and point angle on surface roughness produced when drilling Mild steel. design method, was performed drilling with cutting parameters in Mild steel (see Fig. 3). The orthogonal array, signal-to-noise ratio, and analysis of variance (ANOVA) were employed to investigate the optimal drilling parameters of Mild steel. From the analysis of means and ANOVA, the optimal combination levels and the significant drilling parameters on surface roughness were obtained. The optimization results showed that the combination of low cutting speed, low feed rate, and medium point angle is necessary to minimize surface roughness. The effect of parameters such as Cutting speed, feed rate and point angle and some of their interactions were evaluated using ANOVA analysis with the help of MINITAB 15 @ software. The purpose of the ANOVA was to identify the important parameters in prediction of Surface roughness. After the analysis of the results in ANOVA table no (4), cutting speed is found to be the most significant factor (F-value 366.67) & its contribution to Surface roughness is 51.908% followed by feed rate (F-value 174.285) the factor that sub significantly affected the surface roughness which had contribution of 26.628% respectively.

After the analysis of the results in ANOVA table (5), cutting speed of material removal rate is found to be the most significant factor (F-value 110) & its contribution to MRR is 39.5% followed by feed rate (F-value 100) the factor that sub significantly affected the surface roughness which had contribution of 35.4 % respectively.

Figure 1 shows the main effect of MRR of each factor for various level condition it was increase in spindle speed then increase in the material removable rate and, the increase in the feed rate then decrease the decrease the MRR and
depth of cut increase beginning in machining process in decrease MRR and after some process increase Depth of cut and slightly increase MRR. According to predicted optimal parameter setting we have conducted the confirmation test and found MRR 1.46 cm3/min which shows the successful implementation of this approach.

Figure 2 shows the main effects of SR of each factor for various level conditions. According to predicted optimal parameters setting we have conducted the confirmation test and found surface roughness 2.12 (Ra) which shows the successful implementation of this approach in case of drilling machine optimization of mild steel work piece

7] CONCLUSION:

The following conclusions can be drawn from this analysis on drilling processes:

1. Taguchi method has been used to determine the main effects, significant factors and optimum machining conditions to obtain better performance characteristics.

2. Multiple performance characteristics such as tool life, cutting force, surface roughness and the overall productivity can be improved by using Taguchi method.

3. The optimum speed for a particular setup is affected by many factors, including Composition, hardness & thermal conductivity (k) of material, Depth of hole, efficiency of cutting fluid type, operating condition and stiffness of drilling machines, Stiffness of work piece, fixture and tooling (shorter is better), Quality of holes desired, life of tool before regrind or replacement.

4. 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.

5. This paper shows vast feasibility of machining mild Steel on drilling machine with HSS tool.

6. Signal to noise ratio has been used to determine optimum machining operating parameters to improve quality of drilling hole in mild steel.

7. The Spindle speed of drilling machine Tool mainly affects the Surface roughness.

8. Feed Rate largely affects the Material removal rate.

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