Optimization of Drilling Parameters for Minimum Surface Roughness Using Taguchi Method in 7075 Alloy

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Abstract: The objective of the present work is to optimize process parameter such as cutting speed, feed, and drill diameter. 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. This paper focuses on the optimization of drilling parameters using the Taguchi technique to obtain minimum surface roughness (Ra). A number of drilling experiments were conducted using the L9 orthogonal array on a radial drilling machine. The experiments were performed on 7075 alloy with carbide tool drill. Analysis of variance (ANOVA) was employed to determine the most significant control factors affecting the surface roughness. The cutting speed, feed rate and drill diameter were selected as control factors. After the nine experimental trials, it was found that the drill diameter was the most significant factor for the surface roughness. The results of the confirmation experiments showed that the Taguchi method was notably successful in the optimization of drilling parameters for better surface roughness. Commercial software package MINITAB17 is used for performing the analysis.

Introduction
Drilling is a process of producing round holes in a solid material or enlarging existing holes with the use of multi-point cutting tools called drills or drill bits. Drilling is a continuous machining process. Various cutting tools are available for drilling, but the most common is the twist drill. Wide variety of drill processes are available to serve different purposes (core drilling, step drilling, counter boring, counter sinking, reaming, center drilling, gun drilling etc.). With the rapidly growing technologies quality and productivity are the major concern. Productivity is concerned with the material removal rate (MRR) during machining operation and quality refers to the product characteristics. So the quality and productivity can be improved through parameters optimization. There are number of research works related to various drilling parameters optimization for achieving the performance responses. Among them surface roughness, material removal rate (MRR) and thrust forces on drill bit are the major performance responses. Material removal rate (MRR) is the primary response variable while considering productivity. The material removal rate depends on input parameters and the machine during drilling operation. So the primary objective of optimization analysis during drilling operation is to optimize the input parameters. Also material removal rate (MRR) play a major role in surface roughness. The primary objective in all the research works relating to drilling parameter optimization is to optimize the input parameters such as spindle speed, feed rate, drill bit diameter etc. Simply the optimization means improving the material removal rate and reducing the surface roughness value. The other aspect governing the drilling parameter optimization is quality of the product. Quality relating to the product characteristics like surface roughness, wear resistance, cost etc. Design of experiment and analysis of experimental data play a significant role in parameters optimization and cost of optimization. Among all the design of experiment techniques Taguchi method is the simplest one. Analysis of variance (ANOVA) is used for analyzing the data obtained during experiment. The grey relational analysis is the most accurate and effective analysis tool for the data obtained during CNC drilling. Many of the researches in parameter optimization uses wide variety of design experiments and analysis focused on different performance parameters and different materials. So this paper centered on drilling parameters optimization in different material using Taguchi method.

Experimentation
Design Of Experiment (DoE):
Design of Experiment is a powerful approach to improve product design or improve process performance where it can be used to reduce cycle time required to develop new product or processes. Design experiment is a test or series of test that the input variable (parameter) of a process is change so that observation and identifying corresponding changes in the output response can be verify. The
result of the process is analyzed to find the optimum value or parameters that have a most significant effect to the process. The objectives of the experiment may include.

**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. 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.

**TAGUCHI METHOD**
The Taguchi technique is a methodology for finding the optimum setting of the control factors to make the product or process insensitive to the noise factors. Taguchi’s techniques have been used widely in engineering design, and can be applied to many aspects such as optimization, experimental design, sensitivity analysis, parameter estimation, model prediction, etc. The distinct idea of Taguchi’s robust design that differs from the conventional experimental design is that of designing for the simultaneous modelling of both mean and variability. Taguchi based optimization technique has produced a unique and powerful optimization discipline that differs from traditional practices. While, traditional experimental design methods are sometimes too complex and time consuming, Taguchi methodology is a relatively simple method.

Taguchi method uses a special highly fractionated factorial designs and other types of fractional designs obtained from orthogonal arrays (OA) to study the entire experimental region of interest for experimenter with a small number of experiments. This reduces the time and costs of experiments, and additionally allows for an optimization of the process to be performed. The columns of an OA represent the experimental parameters to be optimized and the rows represent the individual trials (combinations of levels).

Traditionally, data from experiments is used to analyze the mean response. However, in Taguchi method the mean and the variance of the response (experimental result) at each setting of parameters in OA are combined into a single performance measure known as the signal-to-noise (S/N) ratio. Depending on the criterion for the quality characteristic to be optimized, different S/N ratios can be chosen:

- Smaller-The-Better
- Larger-The-Better

**Smaller – The –Better**
The Signal-To-Noise ratio for the Smaller-The-Better is:

\[
S/N = -10 * \log \left( \frac{\text{mean square of the response}}{n} \right)
\]

Where \( n \) is the number of measurements in trial/row, in this case \( n=1, 2, \ldots, 9 \) and \( Y_i \) is the \( i \)th measured value in a run/row, \( i =1, 2 \ldots \).

**Larger – The –Better**
The Signal-To-Noise ratio for the bigger-the-better is:

\[
S/N = -10 * \log \left( \frac{\text{mean square of the inverse of the response}}{n} \right)
\]

**Nominal – The –Better**
The S/N equation for the Nominal-The-Best is:

\[
S/N = 10 * \log \left( \frac{\text{square of the mean divided by the variance}}{n} \right)
\]

**WORK MATERIAL DETAILS**

- Work material – 7075 alloy
- Work material thickness – 12 mm

**MATERIAL SPECIFICATION:**

<table>
<thead>
<tr>
<th>Component</th>
<th>Wt. %</th>
<th>Component</th>
<th>Wt.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al</td>
<td>87.1 - 91.4</td>
<td>Mg</td>
<td>2.1 - 2.9</td>
</tr>
<tr>
<td>Cr</td>
<td>0.18 - 0.28</td>
<td>Mn</td>
<td>Max 0.3</td>
</tr>
<tr>
<td>Cu</td>
<td>1.2 - 2</td>
<td>Mn</td>
<td>Max 0.3</td>
</tr>
<tr>
<td>Zn</td>
<td>5.1 - 6.1</td>
<td>Si</td>
<td>Max 0.4</td>
</tr>
<tr>
<td>Fe</td>
<td>Max 0.5</td>
<td>Other, each</td>
<td>Max 0.05</td>
</tr>
</tbody>
</table>
WORKPIECE MATERIAL:

SURFACE FINISH MEASUREMENT SURFTEST (SJ-210):

SurfTest SJ-210 (Portable surface roughness tester) instrument is widely used to measure the shape or form of components. A profile measurement device is usually based on a tactile measurement principle. The surface is measured by moving a stylus across the surface. As the stylus moves up and down along the surface, a transducer converts these movements into a signal which is then transformed into a roughness number and usually a visually displayed profile. Multiple profiles can often be combined to form a surface representation. SurfTest SJ-210 is shown in figure 2.

PARAMETRES AND OBSERVATION

<table>
<thead>
<tr>
<th>FACTORS</th>
<th>LEVEL 1</th>
<th>LEVEL 2</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting speeds (RPM)</td>
<td>1200</td>
<td>1350</td>
<td>1500</td>
</tr>
<tr>
<td>Feed (mm/rev)</td>
<td>200</td>
<td>250</td>
<td>300</td>
</tr>
<tr>
<td>Drill diameters (mm)</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

Table 1: Drilling parameters and their levels

Among the all given drilling parameters, the drill diameters and depth of drill is kept constant and the cutting speed (RPM) and feed (mm/rev) is varied and the operation is carried out in the CNC milling machine and the diameters of each hole and the surface roughness is calculated and tabulated in the table 2.

Table 3: Surface Roughness Calculation

IV. ANALYSIS

ANALYSIS OF RESULTS

The effect of various parameters such as cutting speed, feed, drill diameter and interaction between drill material and cutting speed were evaluated using ANOVA. A confidence interval of 95% has been used for the analysis. 9 trials were conducted in the experiment using L9 experimental design. One repetition for each of 9 trials was completed to measure Signal to Noise ratio (S/N ratio).
ANALYSIS OF VARIANCE

The results were analyzed using ANOVA for identifying the significant factors affecting the performance measures. The Analysis of Variance (ANOVA) for the mean surface roughness at 95% confidence interval is given in Table 6. The variation data for each factor were F-tested to find significance of each. The principle of the F-test is that the larger the F value for a particular parameter, the greater the effect on the performance characteristic due to the change in that process parameter. ANOVA table shows that drill diameter with F value of 0.59 cutting speed with F value of 0.26 and feed with F value of 0.48, are the factors that significantly affect the surface roughness. All others factors, namely, feed and cutting speed were found to be insignificant. Table 5 shows the ranks of various factors in the terms of their relative significance. Drill diameter has the highest rank, signifying highest contribution to surface roughness and drill cutting speed has the lowest rank and observed to be insignificant in affecting surface roughness. Main effect plot for the mean surface roughness is shown in the Figure 6, which shows the variation of surface roughness with the input parameters. As it can be, seen surface roughness decrease with increase in drill diameter from 4 mm to 12 mm. Surface roughness increased with increase in feed from 0.1 to 0.15.

ANALYSIS OF VARIANCE FOR SR, USING ADJUSTED SS FOR TESTS

<table>
<thead>
<tr>
<th>SOURCE OF VARIATION</th>
<th>D.F.</th>
<th>SUM OF SQUARES</th>
<th>VARIANCE</th>
<th>F RATIO (F)</th>
<th>P VALUE (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPEED</td>
<td>2</td>
<td>1.2311</td>
<td>0.6156</td>
<td>5.90</td>
<td>0.145</td>
</tr>
<tr>
<td>FEED</td>
<td>2</td>
<td>0.0097</td>
<td>0.4404</td>
<td>4.22</td>
<td>0.191</td>
</tr>
<tr>
<td>DEPTH OF CUT</td>
<td>2</td>
<td>0.2458</td>
<td>0.1229</td>
<td>1.18</td>
<td>0.459</td>
</tr>
<tr>
<td>ERROR</td>
<td>2</td>
<td>0.2065</td>
<td>0.1033</td>
<td>99.9%</td>
<td></td>
</tr>
<tr>
<td>TOTAL</td>
<td>8</td>
<td>2.5661</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6: Analysis Of Variance For SR Using Adjusted SS For tests

RESULTS AND DISCUSSION

Taguchi method is done with smaller – the – better criteria, which means that minimum surface roughness is the response. Figure 9 shows the main effect plot for S/N rations corresponding to the input parameters. From the figure it is clear that 1200 Rpm speed have higher S/N ration. Similarly the feed rate is 0.200 mm/rev. So the optimum sequence of parameters are A 1 – B1 – C1. Where A, B and C corresponding to cutting speed in rpm, feed rate in mm/rev & drill diameter in mm. Figure 10 shows the main effect plot for means, which is used for finding the optimum cutting parameters.

CONCLUSIONS

In this study, drilling of 7075alloy is carried out with the input drilling parameters considered as spindle speed, feed rate and drill diameter, and the response obtained is hole surface roughness. The drilling parameters are optimized with respect to multiple performances in order to achieve a good quality of holes in drilling of cast iron. Optimization of the parameters was carried out using Taguchi method.

It was identified that a spindle speed of 1200 rpm, drill diameter of 8mm and a feed rate of 0.2 mm/rev is the optimal combination of drilling parameters that produced a high value of S/N ratios of hole roughness.
REFERENCES


[8]. R. Nicole, “Title of paper with only first word capitalized,” J. Name Stand. Abbrev, in press.