A Review on Optimization of Cutting Parameters in Drilling using Taguchi Method

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Abstract: The aim of this paper is to make a review on Optimization of Cutting Parameters in Drilling Using Taguchi Method to get minimum surface roughness. The settings of the parameter were determined by using Taguchi’s orthogonal array. Analysis of variance (ANOVA), signal to noise (S/N) ratio, regression analysis were employed to find out the optimal value by studying the effects of the cutting parameter.

Keywords — Taguchi method, Orthogonal array, Anova, Signal to noise ratio, Regression analysis, cutting parameters.

I. Introduction
Drilling is a machining process used to make hole of circular cross section by using a drill bit. For achieving good quality at low cost there is a strong need of recognising the optimal cutting parameters. Based on work piece material, tool material, tool dimension and some other criteria, the cutting parameters are selected for each process. Parameters such as cutting speed, feed rate, depth of cut, cutting fluid, tool diameter can affect every process. For designing high quality systems efficiently and effectively the Taguchi method is very commonly used in process optimization.

1.1 Taguchi Method
Taguchi method is a very simple and effective methodology to obtain robust design which is minimally affected by variation. Taguchi method gained popularity in engineering and science community as the user can apply with limited knowledge of statistics for obtaining good quality at low cost. Taguchi uses signal to noise (S/N) ratio and orthogonal array to achieve optimal condition of the process parameter. S/N ratio is divided into three groups i.e. 1) Smaller the better, 2) Larger the better, 3) Nominal the best type.

Fig 1: Taguchi’s method
Surface Roughness is a measure of the surface texture of a manufactured surface. It is the fluctuation of the surface from a reference plane. Low fluctuation from the reference line means low roughness. Optimal settings of the cutting parameters are most important for obtaining low surface roughness. Complete definition of a surface includes Ra (Arithmetic Average Roughness), Rp (Maximum Peak Height), Rv (Maximum Valley Depth) and Rt (Maximum Peak-to-Valley Roughness Height), Rz (average Rt over a given length).

Fig 2: General surface roughness curve

The above figure shows the roughness of the machined surface. Average roughness value is shown by mean line at every instantaneous point.

II. LITERATURE REVIEW

Yogendra Tyagi, Vedansh Chaturvedi, et al. (2012) [1] investigated the effect of cutting parameters spindle speed, feed rate and depth of cut for maximizing material removal rate and minimizing surface roughness in drilling mild steel. Taguchi L9 orthogonal array is used. Results are analyzed using Taguchi DOE software. They concluded that spindle speeds affects most surface roughness and feed rate largely affects Material removal rate.

M Sundeep, M Sudhahar, et al. (2014) [2] have done an experimental investigation on drilling of Austenitic stainless steel (AISI 316) using Taguchi L9 array. Spindle speed, feed rate and drill diameter was taken as process parameter. It was found that spindle speed plays the most dominating role in surface finish as well as Material removal rate in drilling.

Kadam Shirish, M. G. Rathi (2013) [3] focused on optimization of drilling parameters using the Taguchi technique. L9 orthogonal array has been used to drill on EN-24 steel blocks. Uncoated M32 HSS twist drill was used under dry condition. Cutting speed, feed rate and depth of hole were taken as process parameter. S/N ratio was employed to get optimal control factors. They found that cutting speed was the main significant factors on surface roughness and the tool life.

Turgay Kıvak, Gurcan Samtas, et al. (2012) [4] investigated the effect of cutting parameters cutting tool, cutting speed and feed rate on drilling of AISI 316 stainless steel. Experiments were done in CNC vertical machine using Taguchi L16 orthogonal array. Coated and uncoated M35 HSS twist drill bit were used under dry condition for this purpose. Analysis of variance was done to draw the effects of the control factors. It was found that cutting tool was the most significant factor on surface roughness and feed rate was the most significant factor on thrust force.

Adem Çiçek, Turgay Kıvak, et al. (2012) [5] investigated the effect of deep cryogenic and cutting parameters on surface roughness as well as roundness error in drilling of AISI 316 austenitic stainless. Cutting tools, cutting speeds and feed rate was taken as control factors. M35 twist drill bit were used for doing the experiment. L8 orthogonal array was used and multiple regression analysis was performed to find out predictive equation of surface roughness. A confirmation experiment has showed Taguchi method precisely optimized the drilling Parameters in drilling AISI 316 steel.

A. Navanth, T. Karthikeya Sharma (2013) [6] focused on optimization of drilling parameter for minimum surface roughness and hole diameter by using Taguchi methodology. Al 2014 material and HSS twist drill bit has been taken for performing experiment. L18 orthogonal array has been used and the result obtained were analyzed in MINITAB 16. Analysis of variance (ANOVA) was used to find out the optimal factors from cutting tool, spindle speed and feed rate. Optimal values are spindle speed 300 rpm, point angle and helix angle 130°/20° and feed rate .15 mm/rev for minimum roughness.

J. Pradeep Kumar, P. Packiaraj (2012) [7] investigated the effect of cutting parameters such as cutting speed, drill tool diameter feed and feed on surface finish of OHNS material using HSS spiral drill. L18 orthogonal array, S/N ratio, ANOVA and Regression analysis has been employed to study the effect of drilling parameters on surface roughness value. Experimental data was analyzed using MINITAB 13 and it was found that speed and feed plays most dominating factors in surface roughness, tool wear, material removal rate.

Reddy Sreenivasulu (2014) [8] focused on optimization of surface roughness in drilling of Al 6061 using Taguchi design method and artificial neural network method. Cutting speed, feed rate, drill diameter, clearance angle and point angle were taken as cutting parameters and HSS twist drill bit as a tool. L27 orthogonal array, ANOVA, S/N ratio were employed to study the effects of the control factors. ANOVA analysis showed cutting speed, feed rate, drill diameter, clearance angle and point
angle all were significant on surface roughness. The paper shows Optimal settings for roughness are speed 800 rpm, feed rate ,.3 mm/rev , drill dia 10 mm, point angle 118°, clearance angle 4°.

B. Shivapragash, K. Chandrasekaran, et al. (2013) [9] studied optimization of the process parameters spindle speed, feed rate, depth of cut to investigate their influence in drilling composite Al-TiBr2. Taguchi method with grey relational analysis were used to optimize the factors. L9 orthogonal array has been used and optimal settings found for better surface finish were spindle speed (1000 rpm), feed rate (1.5 mm/rev), depth of cut 6 mm.

Nalawade P.S. and Shinde S.S. (2015) [10] optimizes the cutting parameters speed, depth of cut, feed and type of tool to get better Surface Finish and Hole Accuracy in dry Drilling of EN-31 material. Taguchi L9 orthogonal array , S/N ratio, ANOVA, Regression analysis were done to find out the optimal settings. Optimal settings for surface roughness were Cutting speed (30 m /min), feed (.2 mm/min), type of tool (HSS uncoated).

Sathish Rao U And Lewlyn J.R. Rodrigues (2014) [11] have made an attempt to study the effect of spindle speed, feed rate, drill diameter, fibre orientation on tool wear during drilling GFRP components in dry condition. HSS drill bit was used for the experiment. Taguchi L9 orthogonal array has been used. S/N ratio, ANOVA, regression analysis was used to find out the optimal settings. It has been found that speed, feed rate , drill diameter has significant effect on tool wear.

Nisha Tamta, R S Jadoun (2015) [12] analyzed the effect of spindle speed, feed rate, drilling depth on drilling Aluminium alloy 6082 with the help of CNC machine. Taguchi L9 orthogonal array was used to perform the experiment. Signal to noise ratio (S/N), analysis of variance (ANOVA) were used to analyze the effects drilling parameters on surface roughness. For analyzing statistical software MINITAB-15 has been used. It has been found that spindle speed 3000 rpm, feed rate 15 mm/min, drilling depth 9 mm were the optimum value. According to the paper drilling depth was the most significant factor for surface roughness followed by spindle speed.

Srinivasa Reddy, S. Suresh, et al. (2014) [13] investigated the impact of cutting parameters such as cutting speed, point angle and feed rate on surface roughness in drilling of AL 6463 material. HSS drill bit was used and the experiment was done in CNC drilling machine using Taguchi L9 orthogonal array. Signal to noise ratio (S/N), analysis of variance (ANOVA) has been employed to find out the optimal drilling parameter. It was found that Cutting speed, feed rate and point angle plays significant role on surface roughness during drilling operation of AL 6463 material.

Arshad Noor Siddiquee, Zahid A. Khan, et al. (2014) [14] focused on optimizing drilling parameters such as cutting fluid, speed, feed and hole depth in drilling AISI 312 material. Experiments were done in CNC lathe machine using solid carbide cutting tool. Taguchi L18 orthogonal array has been used for the experiment. Signal to noise ratio (S/N), analysis of variance (ANOVA) were used to find out the effects of cutting parameters on surface roughness. It has been found that in presence of cutting fluid, speed 500 rpm, feed .04 mm/sec, hole depth 25 mm were the optimum value for surface roughness. Anova analysis showed that speed was the most significant factor followed by cutting fluid, feed and hole depth for surface roughness value.

Vishwajeet N. Rane, Ajinkya P.Edlabadkar, et al. (2015) [15] focused in optimizing drilling parameters such as cutting speed, feed and point angle for resharpened HSS twist drill bit on hardened boron steel using Taguchi method. L16 orthogonal array has been used to perform the experiment in a double spindle drilling machine. Analysis of variance was employed to find out effects of control factors on surface roughness. It was found that point angle was the main significant factor for tool wear and feed rate for surface roughness.

**TABLE 1: SUMMERY OF LITERATURE SURVEY**

<table>
<thead>
<tr>
<th>Referenc e No</th>
<th>Year</th>
<th>Author’s Name</th>
<th>Workpiece Material</th>
<th>Input Parameter</th>
<th>Method used</th>
<th>Output Parameter</th>
<th>Most Significant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2012</td>
<td>Yogendra Tyagi, Vedansh Chaturvedi, et al.</td>
<td>Mild steel</td>
<td>Spindle speed, Feed rate, Depth of cut</td>
<td>Taguchi Method</td>
<td>Surface roughness , Material removal rate</td>
<td>Spindle speed, Feed rate</td>
</tr>
<tr>
<td>No.</td>
<td>Year</td>
<td>Authors</td>
<td>Material</td>
<td>Cutting Tool</td>
<td>Cutting Speed</td>
<td>Feed rate, Depth of hole</td>
<td>Taguchi Method</td>
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<tr>
<td>3</td>
<td>2013</td>
<td>Kadam Shirish, M. G. Rathi</td>
<td>EN 24</td>
<td>Cutting, Feed rate, Depth of hole</td>
<td>Taguchi Method</td>
<td>Surface roughness, Tool life, Thrust force</td>
<td>Cutting Speed</td>
</tr>
<tr>
<td>4</td>
<td>2012</td>
<td>Turgay Kivak, Gurcan Samtas, et al</td>
<td>AISI 316</td>
<td>Cutting tool, Cutting speed, Feed rate</td>
<td>Taguchi Method</td>
<td>Surface roughness, Thrust force.</td>
<td>Cutting tool, Feed rate</td>
</tr>
<tr>
<td>5</td>
<td>2012</td>
<td>Adem Çiçek, Turgay Kivak, et al.</td>
<td>AISI 316</td>
<td>Cutting tools, Cutting speeds, Feed rate</td>
<td>Taguchi Method</td>
<td>Surface roughness, Roundness error</td>
<td>Cutting speed, Feed rate</td>
</tr>
<tr>
<td>6</td>
<td>2013</td>
<td>A. Navanth, T. Karthikeya Sharma</td>
<td>Al 2014</td>
<td>Cutting tools, Spindle speeds, Feed rate</td>
<td>Taguchi Method</td>
<td>Surface roughness, Hole diameter</td>
<td>Spindle speeds(300 rpm optimum), Feed rate(.15 mm/rev optimum)</td>
</tr>
<tr>
<td>7</td>
<td>2012</td>
<td>J.Pradeep Kumar, P.Packiaraj</td>
<td>OHNS</td>
<td>Cutting speed, feed, Drill tool diameter</td>
<td>Taguchi method</td>
<td>Surface roughness, Tool wear, Material removal rate</td>
<td>Speed, Feed</td>
</tr>
<tr>
<td>8</td>
<td>2014</td>
<td>Reddy Sreenivasulu</td>
<td>Al 6061</td>
<td>Cutting speed, Feed rate, Drill diameter, Point angle and Clearance angle</td>
<td>Taguchi design method, Artificial neural network method.</td>
<td>Surface roughness</td>
<td>Cutting speed, Feed rate, Drill diameter,</td>
</tr>
<tr>
<td>9</td>
<td>2013</td>
<td>B.Shivapragash, K.Chandrasekar, et al</td>
<td>MMC Al-TiBr2</td>
<td>Spindle speed, Feed rate, Depth of cut</td>
<td>Taguchi method, Grey Relational Analysis</td>
<td>Surface finish</td>
<td>Spindle speed, Feed rate</td>
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<tr>
<td>10</td>
<td>2015</td>
<td>Nalawade P.S. and Shinde S.S.</td>
<td>EN-31</td>
<td>Speed, Depth of cut, Feed, Type of tool</td>
<td>Taguchi Method</td>
<td>Surface Finish, Hole Accuracy</td>
<td>Speed, Feed, Type Of Tool, Drill Depth</td>
</tr>
<tr>
<td>11</td>
<td>2014</td>
<td>Sathish Rao U, Lewlyn L.R. Rodrigues</td>
<td>GFRP</td>
<td>Spindle speed, Drill diameter, Feed rate, Fibre orientation</td>
<td>Taguchi method</td>
<td>Tool wear</td>
<td>Cutting speed, Feed rate, Drill diameter</td>
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<tr>
<td>12</td>
<td>2015</td>
<td>Nisha Tamta1, R S Jadoun</td>
<td>Aluminium alloy 6082</td>
<td>Spindle speed, Feed rate, Drilling depth</td>
<td>Taguchi method</td>
<td>Surface roughness</td>
<td>Drilling depth, Spindle speed</td>
</tr>
<tr>
<td>13</td>
<td>2014</td>
<td>Srinivasa Reddy, S. Suresh, et al</td>
<td>AL 6463</td>
<td>Cutting speed, Feed rate, Point angle</td>
<td>Taguchi method</td>
<td>Surface roughness</td>
<td>Spindle speed, Feed rate, Point angle</td>
</tr>
<tr>
<td>14</td>
<td>2014</td>
<td>Arshad Noor Siddiquee, Zahid A. Khan, et al</td>
<td>AISI 312</td>
<td>Cutting fluid, Speed, Feed, Hole depth</td>
<td>Taguchi method</td>
<td>Surface roughness</td>
<td>Speed, Cutting fluid, Feed, Hole depth</td>
</tr>
<tr>
<td>15</td>
<td>2015</td>
<td>Vishwajeet N. Rane, Ajinkya P.Edlabadkar, et al</td>
<td>Harden Boron steel</td>
<td>Cutting speed, Feed, Point angle</td>
<td>Taguchi method</td>
<td>Tool life, Surface roughness</td>
<td>Point angle, Feed rate</td>
</tr>
</tbody>
</table>
III. CONCLUSION

From the literature survey we observed that many researchers took input parameters: cutting speed, feed rate and depth of cut and few took input parameter: Cutting fluid, drill tool diameter, cutting tools, point angle, clearance angle, type of tool and output parameters were taken: surface roughness, material removal rate (MRR), Thrust force, tool wear, Hole diameter, Hole Accuracy, Roundness error. It is found that for surface roughness the most significant parameters are speed, feed and drill diameter, cutting fluids and least dominant parameter is DOC.

REFERENCES