Recently EN8 steel finding many applications in manufacturing of parts such as axle, shaft gear and fasteners due to their high tensile strength property. Optimum machining parameters of milling operations are great concern with manufacturing environment. In this experimental investigation was observed the machining performance with various cutting speed, feed and depth of cut using side and face milling cutter. Mainly surface roughness where investigated employing Taguchi design of experiments and analysis of variance (ANOVA). The significant machining parameters are identified by using signal to noise ratio. The result of the experiments indicates cutting speed play a dominating role in surface roughness in milling process parameters.

**Keywords:** EN8 steel, Machining parameters, Taguchi methodology, S/N ratio, ANOVA

**INTRODUCTION**

Metal cutting is one of the important widely used manufacturing processes in engineering industries. The study of metal cutting focuses the work material, tools, machining parameters and cutting fluid which influencing process efficiency and output quality characteristics. EN8 steel is a popular grade of medium carbon steel, which readily machinable in any condition which best suitable for high tensile strength and wear resistance components. It is available in heat treated forms posses good homogeneous metallurgical structure and gives consistent machining and mechanical properties. There are relatively few researches releasing to surface roughness with using side and face milling cutter in hardened steel. Zhang et al. (2007) used Taguchi design of optimization to predict surface roughness CNC milling operation. El-Sonbaty et al. (2008) used artificial neural networks and traced geometry approach to predict the surface roughness profile milling operations. Palanisamy et al. (2008) using regression the end milling operation. Routara et al. (2009) by using RSM the surface modeling and optimization in milling process. Baek et al. (2001) by RSM optimized the feed rate in face
milling operation. Ghani et al. (2004) explain high cutting speed, feed and depth of cut were adopted for low surface roughness is obtained for high hardened steel. Yang and Chen (2001) analyze mathematical model of surface roughness were established by means of design of experiments. Tongchao et al. (2010) experimentally investigated at the effect of cutting parameters on cutting forces and surface roughness in hard milling. Previous study provides much valuable information for under studying of surface roughness in milling process, very few researches were conducted to investigate surface roughness in hardened steel.

EXPERIMENTAL SETUP

Machine Details
The test was conducted on universal milling machine with maximum spindle speed 1440 rpm and 25 kw drive motor without using cutting fluid (Figures 1 and 2).

Milling Cutter
A seco R 220.53 – 0125-09 – 8C tool holder with diameter 125mm side and face milling cutter was used in this experiments [cutting rake angle 10°,axial angle 20° and radial rake angle 5° was used in milling operation].

Work Material
A 50 mm and 12 mm thickness EN8 steel flat plate were used in this experimental investigation (Tables 1 and 2).

Surface Roughness Tester
The surface roughness values are measured by MITUTOYO SURF TESTER SJ 201 P having cut of length of 0.25-25 mm with diamond stylus (Figure 3).

METHODOLOGY
The major steps involved in design of Experiments:

- State the problem.
- State the objectives of experiments.
Design of Experiments

Three levels were specified for each factors indicated in the Table 3, first column is assigned for cutting speed \([V_c]\), second column is to feed rate \([f]\) and third column to the depth of cut \([d]\). The test was performed for each combination and resulting in a total of 9 experiments which allows analysis of variance of results (Table 3).

**Taguchi Design of Experiments**

Taguchi method is a powerful tool in quality optimization that makes use of a special design of Orthogonal Array (OA) to examine number of experiments used to design the orthogonal array for 3 parameters like cutting speed, feed rate and depth of cut for each parameters three different levels. The minimum number of experiments to be conducted for the parametric optimization was calculated as:

\[
\text{Minimum experiments} = [(L - 1) \times P] + 1 \\
= [(3 - 1) \times 3] + 1 = 7 \approx L9.
\]

The \(S/N\) ratio of the smaller the better characteristics can be expressed as:

\[
S/N = -10 \log \frac{1}{j \cdot y_i^2}
\]

where,

- \(j\) is the number repetition of experiments.
- \(y_i\) is the average measured rate of experimental data.

**RESULTS AND DISCUSSION**

The experimental investigation on machinability characteristics of EN8 steel with side and face milling cutter during milling
The process was optimized the milling parameters and predict low surface roughness based on taguchi prediction that the bigger different in values of S/N ratio shows more effect on surface roughness (Tables 4 and 5). It can be calculated and concluded by spindle speed is more significant factor and give most contribution on surface roughness of EN8 steel plates.

The result of S/N ratio values of milling parameters were analyzed by analysis of variance method which consists of DOF (Degree of Freedom), S (sum of square), V (Variance) F (variance ratio) and P(significant factor) (Table 6). In most significant values were selected by 5% ($\alpha = 0.05$) from this main effect interaction plot values of milling parameters predict the low value of surface roughness as indicate at spindle speed of 285 m/min, feed rate 0.27 mm/rev and depth of cut 0.4 mm were the best combinations of this experimental work (Figures 4-7).

Table 4: Surface Roughness Values for EN8

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Cutting Speed (Vc) m/min</th>
<th>Feed Rate (f) mm/Rev</th>
<th>Depth of Cut (d) mm</th>
<th>Surface Roughness (Ra) µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>185</td>
<td>0.123</td>
<td>0.4</td>
<td>0.770</td>
</tr>
<tr>
<td>2.</td>
<td>185</td>
<td>0.175</td>
<td>0.8</td>
<td>0.750</td>
</tr>
<tr>
<td>3.</td>
<td>185</td>
<td>0.270</td>
<td>1.2</td>
<td>0.790</td>
</tr>
<tr>
<td>4.</td>
<td>285</td>
<td>0.123</td>
<td>0.8</td>
<td>0.734</td>
</tr>
<tr>
<td>5.</td>
<td>285</td>
<td>0.175</td>
<td>1.2</td>
<td>0.746</td>
</tr>
<tr>
<td>6.</td>
<td>285</td>
<td>0.270</td>
<td>0.4</td>
<td>0.690</td>
</tr>
<tr>
<td>7.</td>
<td>405</td>
<td>0.123</td>
<td>1.2</td>
<td>0.726</td>
</tr>
<tr>
<td>8.</td>
<td>405</td>
<td>0.175</td>
<td>0.4</td>
<td>0.693</td>
</tr>
<tr>
<td>9.</td>
<td>405</td>
<td>0.270</td>
<td>0.8</td>
<td>0.698</td>
</tr>
</tbody>
</table>

Table 5: Response Table for S/N Ratio (Smaller the Better)

<table>
<thead>
<tr>
<th>Level</th>
<th>Cutting Speed</th>
<th>Feed</th>
<th>Depth of Cut</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.272</td>
<td>2.579</td>
<td>2.893</td>
</tr>
<tr>
<td>2</td>
<td>2.818</td>
<td>2.743</td>
<td>2.769</td>
</tr>
<tr>
<td>3</td>
<td>3.030</td>
<td>2.798</td>
<td>2.458</td>
</tr>
<tr>
<td>Delta</td>
<td>0.758</td>
<td>0.219</td>
<td>0.435</td>
</tr>
<tr>
<td>Rank</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 6: Analysis of Variance for Surface Roughness of EN8

<table>
<thead>
<tr>
<th>Sources</th>
<th>DF</th>
<th>Seq SS</th>
<th>Adj SS</th>
<th>Adj MS</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cutting Speed</td>
<td>2</td>
<td>0.0066287</td>
<td>0.0066287</td>
<td>0.0033143</td>
<td>12.14</td>
<td>0.076</td>
</tr>
<tr>
<td>Feed Rate</td>
<td>2</td>
<td>0.0005007</td>
<td>0.0005007</td>
<td>0.0002503</td>
<td>0.92</td>
<td>0.522</td>
</tr>
<tr>
<td>Depth of Cut</td>
<td>2</td>
<td>0.0021247</td>
<td>0.0021247</td>
<td>0.0010623</td>
<td>3.89</td>
<td>0.204</td>
</tr>
<tr>
<td>Error</td>
<td>2</td>
<td>0.0005460</td>
<td>0.0005460</td>
<td>0.0002730</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>8</td>
<td>0.0098000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CONCLUSION

The following conclusions can be drawn based on the results of experimental study on machining EN8 steel during milling process using side and face milling cutter.

- Cutting speed is statistically significant factors influencing the surface roughness in milling process.
- The low surface roughness is obtained at cutting speed of 285 m/min, feed rate 0.27 mm/rev and depth of cut 0.4 mm. This may be ideal machining parameters of EN8 steel plates.
- Milling process is best suitable machining process of EN8 steel other than conventional machining process such as turning, planning and shaping process.
- Side and face milling cutter is suitable for machining EN8 steel which produce good surface finish with required accuracy.

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REFERENCES


