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Research Paper

OPTIMIZATION OF MILLING PARAMETERS OF EN8 USING TAGUCHI METHODOLOGY

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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

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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].

Figure 1: Universal Milling Machine

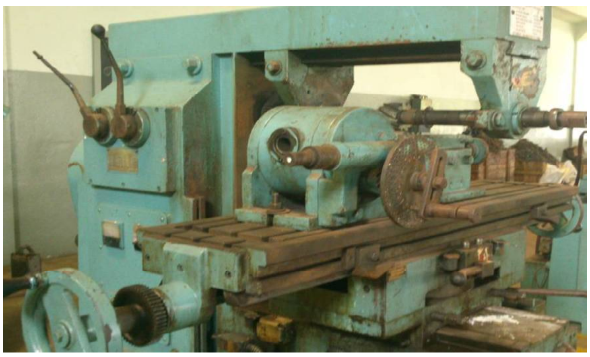
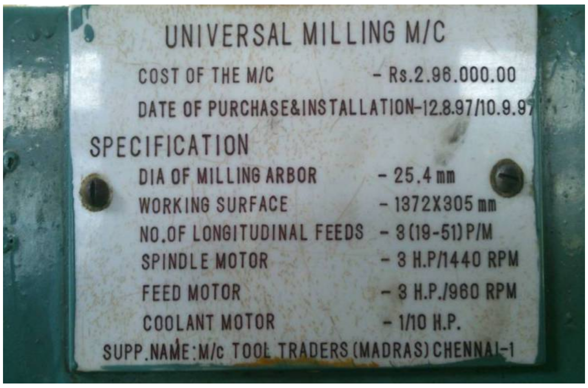


Figure 2: Machine Specification



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).

Table 1: Chemical Composition of EN8 Steel

C	Si	Mn	S	P
0.44	0.40	1.0	0.05	0.5

Table 2: Mechanical Properties of EN8 Steel

Maximum Stress	Yield Stress	Proof Stress (0.2%)	Elongation	Impact Strength	Hardness Value
850 N/mm^{-2}	465 N/mm^2	450 N/mm^2	16%	28 j	255 Brinell

METHODOLOGY

The major steps involved in design of Experiments:

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

Figure 3: Surface Roughness Tester

- Select the quality characteristics of measurement system.
- Select the factors that may influence the selected quality characteristics.
- Identify quality and noise factors.
- Select levels for the factors.
- Select appropriate orthogonal array.
- Select interactions that may influence the selected quality characteristics.
- Assign factors to orthogonal arrays and locate interactions.
- Conduct the tests described by trails in orthogonal array.
- Analyze and interpret results of the experimental trails.
- Conduct confirmation experiment.

Design of Experiments

Three levels were specified for each factors indicated in the Table 3, first column is assigned for cutting speed [*Vc*], 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).

Table 3: L9 Orthogonal Array

Test No.	Cutting Speed (*Vc*)	Feed Rate (*f*)	Depth of Cut (*d*)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

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:

$$S/N = -10 \log 1/j \bullet yi^2$$

where,

j is the number repetition of experiments.

yi 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

Table 4: Surface Roughness Values for EN8

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

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

Level	Cutting Speed	Feed	Depth of Cut
1	2.272	2.579	2.893
2	2.818	2.743	2.769
3	3.030	2.798	2.458
Delta	0.758	0.219	0.435
Rank	1	3	2

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.

Table 6: Analysis of Variance for Surface Roughness of EN8

Sources	DF	Seq SS	Adj SS	Adj MS	F	P
Cutting Speed	2	0.0066287	0.0066287	0.0033143	12,14	0.076
Feed Rate	2	0.0005007	0.0005007	0.0002503	0.92	0.522
Depth of Cut	2	0.0021247	0.0021247	0.0010623	3.89	0.204
Error	2	0.0005460	0.0005460	0.0002730		
Total	**8**	**0.0098000**				

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% (α = 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).

Figure 4: S/N Ratio for Milling Parameters

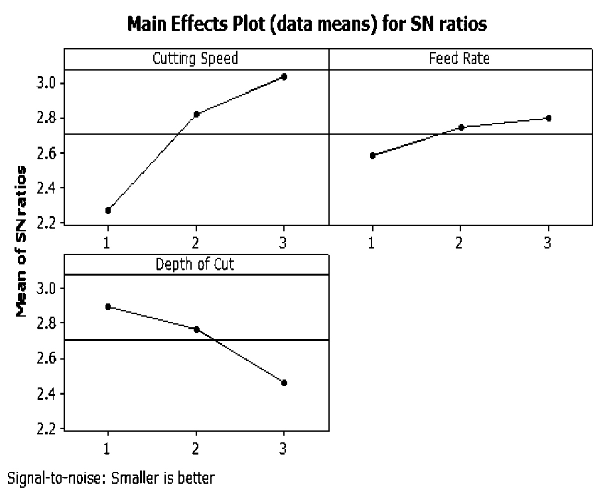


Figure 5: Interaction Plot for Milling Parameters

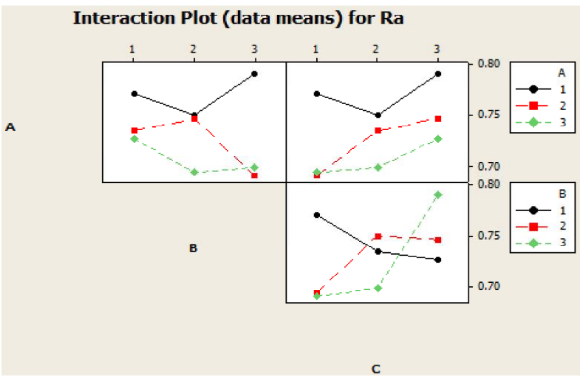


Figure 6: Contour Plot for Milling Parameters

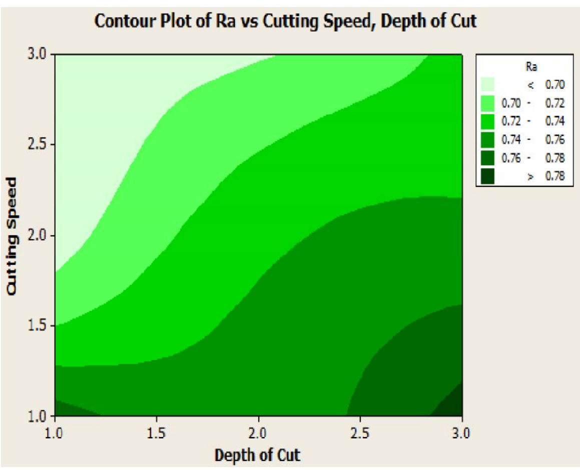
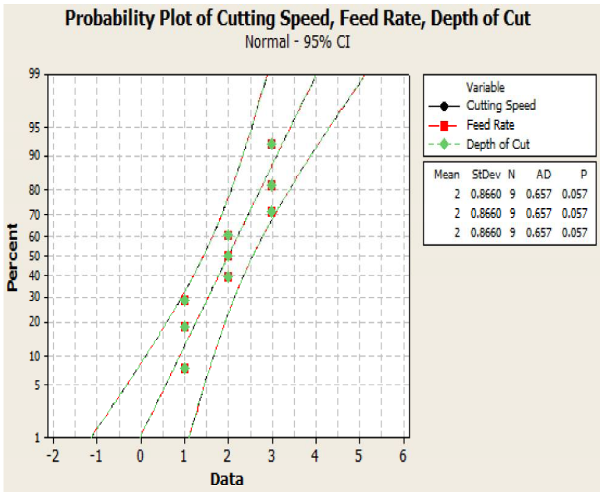


Figure 7: Probability Plot



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 marching 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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