

“Experimental Investigation of EN-8 on Effect of Process Parameters on Cutting Forces and Surface Roughness Using DOE ”

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Abstract

A study has been made in identifying and isolating effects of cutting conditions on cutting forces. Machining tests were conducted using sharp tool and the effects of cutting parameters were studied. In the presented study experiments were conducted on EN8 steel at different cutting parameters. Here chatter starting point length is measured from the free edge of the work piece.

Experiments were conducted on a precision center lathe and the influence of cutting parameters was studied using DOE. Based on the main effects plots obtained through full factorial design, optimum level for surface roughness and cutting force were chosen depth of cut, and the interaction of feed and depth of cut significantly influenced the variance. In case of surface roughness, from the three levels of cutting parameters considered Linear regression equation of cutting force has revealed that feed, the influencing factors were found to be feed and the interaction of speed and feed. As turning of EN8 steel using HSS is one among the major machining operations in manufacturing industry, the revelation made in this research would significantly contribute to the cutting parameters optimization.

Keywords: *EN8, Surface Roughness, Design of Experiments (DOE)*

INTRODUCTION

In this fast changing world customer value and satisfaction becomes a top priority for manufacturing industry. To meet the customer requirement one has to optimize the process parameters in machining. Machining by turning involves the use of a lathe and is used primarily to produce cylindrical or conical parts. Surface finish plays a important role which assures quality, reduces manufacturing cost, assembly time, operation time leading to overall cost reduction. Cutting speed, feed rate, depth of cut, tool work piece material, and tool geometry conditions are the turning parameters which highly affect the performance measures. It is valuable to increase tool life, to improve surface roughness, to reduce cutting force and material removal rate in turning operations through an optimization study.

Design of Experiments (DOE) technique enables the designers to determine simultaneously the individual and interactive effects of many factors that could affect the output results in any design. DOE also provides a full insight of interaction between design elements; therefore, it helps turn any standard design into a robust one. Simply put, DOE helps to pin point the sensitive parts and sensitive areas in designs that cause

problems in Yield. Designers are then able to fix these problems and produce robust and higher yield designs prior going into production.

LITERATURE REVIEW

Jadhav J.S, Jadhav B.R. [1] studied the effect of cutting parameters on cutting force (F_c) & feed force in turning Process. The influence of cutting parameters was studied using analysis of variance (ANOVA) based on adjusted approach. From the experiments the feed rate has significant influence on both the Cutting force and Surface roughness. Cutting Speed has no significant effect on the cutting force as well as the surface roughness of the chosen work piece. Depth of cut has a significant influence on cutting force, but an insignificant influence on surface roughness.

H AOUICI et al. [2] this experimental investigation was conducted to determine the effects of cutting conditions on surface roughness and cutting forces in hard turning of X38CrMoV5-1. This steel was hardened at 50 HRC and machined with CBN tool. Combined effects of three cutting parameters, namely cutting speed, feed rate and depth of cut, on the six performance outputs-surface roughness parameters and cutting force components,

are explored by analysis of variance (ANOVA). Optimal cutting conditions for each performance level are established. Results show how much surface roughness is mainly influenced by feed rate and cutting speed. The depth of cut exhibits maximum influence on cutting force components as compared to the feed rate and cutting speed.

K. AdarshKumar et al. [3] investigated the effects of cutting parameters like spindle speed, feed and depth of cut on surface finish on EN-8. A multiple regression analysis (RA) using analysis of variance is conducted to determine the performance of experimental measurements and to it shows the effect of cutting parameters on the surface roughness. Results show the influence of cutting speed, feed rate, and depth of cut on surface roughness, it was seen that the effect of feed rate is greater than the effect of cutting speed. The feed has the variable effect on surface roughness. The relationship between feed rate and surface roughness is proportional. On surface roughness, the effect of feed rate is more considerable than cutting speed.

P.G.Inamdar et al. [4] studied about optimization of surface roughness in turning operation of EN8 using Taguchi

Method. In this work cutting speed, feed rate and depth of cut are taken as performance parameters to achieve better surface roughness. Taguchi Method is used to obtain the main parametric effect on the surface roughness using 3 levels and factors. L9 orthogonal array and analysis of variance (ANOVA) was carried out with the significance factor of 95%. After the experimentation, it was found that cutting speed has more influenced on the surface roughness in conventional turning process than feed rate and depth of cut.

N. Satheesh Kumar et al. [5] this paper investigates the effect of process parameters in turning of Carbon Alloy Steels in a CNC lathe. The parameters namely the spindle speed and feed rate are varied to study their effect on the surface roughness. The experiments are conducted using one factor at a time approach. The five different carbon alloy steels used for turning are SAE8620, EN8, EN19, EN24 and EN47. The study reveals that the surface roughness is directly influenced by the spindle speed and feed rate. It is observed that the surface roughness increases with increased feed rate and is higher at lower speeds and vice versa for all feed rates.

K. G. Nikam et al. [6] in this paper it was seen that the desired surface roughness was not obtained consistently in turning of EN 8 steel applications. In the present study attempt has been made to investigate the effect of cutting parameters and insert geometry on surface roughness in the finish turning of EN 8 steel. The experiments have been conducted using L9 orthogonal array in a SPEED LX 200 MAJOR CNC lathe machine. Turning process carried out on the EN 8 steel. The optimum cutting condition was determined surface roughness were evaluated by the analysis of variance (ANOVA).

EXPERIMENTAL DETAILS

When the number of processing parameters increases, the classical methods of experimental design are too complex and large numbers of experiments are to be carried out. To overcome these issues, Taguchi method used an orthogonal array to investigate the process parameters with few experiments. In this experimental work, experiments were carried out with three levels of cutting speed; feed and depth of cut were used respectively. The surface roughness was measured by using Mitutoyo SJ-201 instrument. The various cutting parameters and their levels are shown in Table 1.

Table: 1 Cutting Parameters & Levels

Levels	Cutting Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
Level 1	115	0.067	2
Level 2	175	0.111	4
Level 3	263	0.222	6

A. Work-Piece

The experiment was conducted using work piece material namely EN-8 to find out the optimum turning parameters for metal removal rate (MRR) with HSS tool. The tests were carried for a length of

305X32 mm on a Banka lathe Machine tool. Table 2 shows the chemical composition of EN-8.

B. Cutting Inserts

HSS tool with the alloying elements:

manganese, chromium, tungsten, cobalt etc. Tool length of 80mm (approx.) was taken so as to minimize undesirable vibrations, which would influence cutting force and surface roughness. The single

point HSS tool specifications are as follows in Table 3 and Chemical compositions of HSS are shown in Table 4.

Table: 2 Chemical composition of EN-8

C	Si	Mn	S	P
0.4%	0.25%	0.8%	0.015%	0.015%

Table: 3 HSS Tool Specifications

Back Rake Angle	12°
Side Rake Angle	12°
End Relief	10°
End Cutting Edge Angle	30°
Side Cutting Edge Angle	15°
Nose Radius	0.8mm
Cross section	12.5×12.5

Table: 4 Chemical compositions of HSS

C	Si	Mn	Cr
0.90%	0.30%	0.30%	4.10%

C. *Experimental Procedure*



Figure:1 Banka Lathe Machine tool



Figure: 2 Mitutoyo SJ-201 for Surface roughness

The turning tests on the work piece were conducted under dry conditions on Banka lathe Machine tool which have a maximum spindle speed of 2000 rpm. Figure 1 shows the Banka lathe Machine tool.

The surface roughness was measured by using Mitutoyo SJ-201 instrument. Figure 2 shows The dependent variable is surface roughness. In total 27 experiments were

conducted and responses are shown in the Table 4. It gives the various cutting parameters for each experiment the results are measured and shown in the last column of the same Table 4. The different units used here are cutting speed (rpm) Feed- (mm/rev), depth of cut (DOC) – mm, surface roughness Ra - μm . Mini-Tab software was used for Regression analysis. Dry Turning process was used.

RESULTS AND DISCUSSION

The experimental trails were conducted according to the standard L27 Orthogonal array. The use of Taguchi method for

experimental design is to determine significant parameters which affect the machining performance.

Table: 4.1 Experimentation

No of Experiments	Speed N(rpm)	Feed (mm/rev)	D.O.C(mm)	Forces (Kgf)			RoughnessRa(μ m)
				F _x	F _y	F _z	
1	115	0.067	2	3.98	16.38	4.57	3.09
2	115	0.067	4	5.17	20.3	6.23	3.43
3	115	0.067	6	8.59	29.89	7.13	3.76
4	115	0.111	2	5.56	22.87	6.91	4.28
5	115	0.111	4	9.28	36.48	10.11	5.28
6	115	0.111	6	10.44	37.75	9.71	4.43
7	115	0.222	2	8.63	41.63	12.39	5.76
8	115	0.222	4	1.79	16.19	4.53	5.37
9	115	0.222	6	6.19	32.12	13.09	6.55
10	175	0.067	2	4.41	16.96	4.79	2.78
11	175	0.067	4	5.16	18.42	5.95	2.95
12	175	0.067	6	8.5	30.25	7.22	3.05
13	175	0.111	2	5.67	23.25	7.05	4.2
14	175	0.111	4	9.1	35.33	9.33	3.34

15	175	0.111	6	10.68	39.17	9.83	3.90
16	175	0.222	2	8.84	43.16	12.63	6.01
17	175	0.222	4	0.95	11.12	3.36	5.08
18	175	0.222	6	5.62	32.74	13.01	4.58
19	263	0.067	2	4.39	16.81	4.60	2.96
20	263	0.067	4	5.39	17.61	5.94	3.16
21	263	0.067	6	8.5	27.93	7.53	3.22
22	263	0.111	2	5.44	20.17	7.00	3.63
23	263	0.111	4	9.32	32.5	9.43	4.02
24	263	0.111	6	11.62	42.00	11.32	4.58
25	263	0.222	2	8.28	39.51	12.63	5.57
26	263	0.222	4	0.64	8.23	2.28	3.42
27	263	0.222	6	5.7	33.63	12.98	4.45

RESULT

Table: 4.2 Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		9.528	0.596	15.98	0.000	
Speed	-0.043	-0.022	0.443	-0.05	0.962	1.03
Feed	0.150	0.075	0.482	0.16	0.879	1.24
DOC	1.471	0.735	0.443	1.66	0.128	1.01
Speed*Speed	4.410	2.205	0.945	2.33	0.042	2.14
Feed*Feed	-12.58	-6.29	1.37	-4.59	0.001	3.17

DOC*DOC	1.999	0.999	0.908	1.10	0.297	2.12
Speed*Feed	-0.058	-0.029	0.483	-0.06	0.953	1.02
Speed*DOC	-0.314	-0.157	0.491	-0.32	0.756	1.00
Feed*DOC	-3.581	-1.791	0.484	-3.70	0.004	1.01

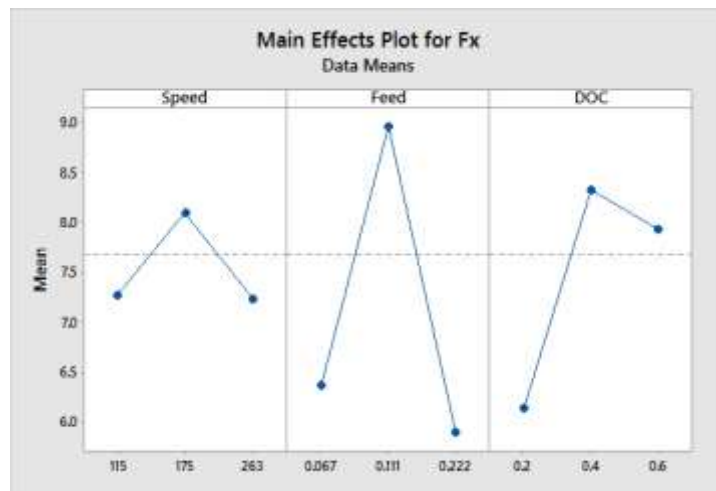


Figure: 3

Table : 5

S	R-sq	R-sq(adj)	R-sq(pred)
1.3934	82.47%	66.68%	0.00%

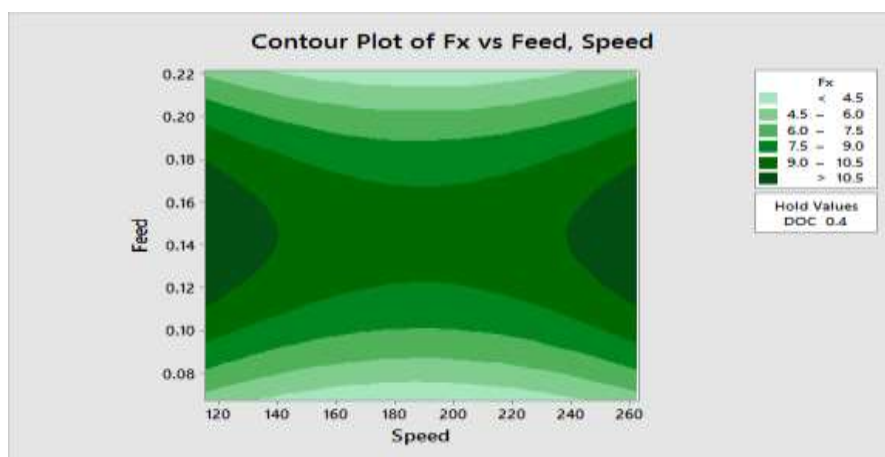


Figure: 4

$$F_x = -3.14 - 0.1475 \text{ Speed} + 350.9 \text{ Feed} + 2.4 \text{ DOC} + 0.000403 \text{ Speed*Speed} - 1048 \text{ Feed*Feed}$$

$$+ 25.0 \text{ DOC*DOC} - 0.0050 \text{ Speed*Feed} - 0.0106 \text{ Speed*DOC} - 115.5 \text{ Feed*DOC}$$

Coded Coefficients

Table: 6

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		38.44	2.61	14.75	0.000	
Speed	-1.12	-0.56	1.93	-0.29	0.778	1.03
Feed	11.28	5.64	2.10	2.68	0.023	1.24
DOC	4.10	2.05	1.94	1.06	0.315	1.01
Speed*Speed	16.14	8.07	4.13	1.95	0.079	2.14
Feed*Feed	-44.93	-22.47	6.00	-3.75	0.004	3.17
DOC*DOC	8.69	4.35	3.97	1.09	0.299	2.12
Speed*Feed	1.21	0.61	2.11	0.29	0.780	1.02
Speed*DOC	-0.03	-0.01	2.15	-0.01	0.995	1.00
Feed*DOC	-10.78	-5.39	2.11	-2.55	0.029	1.01

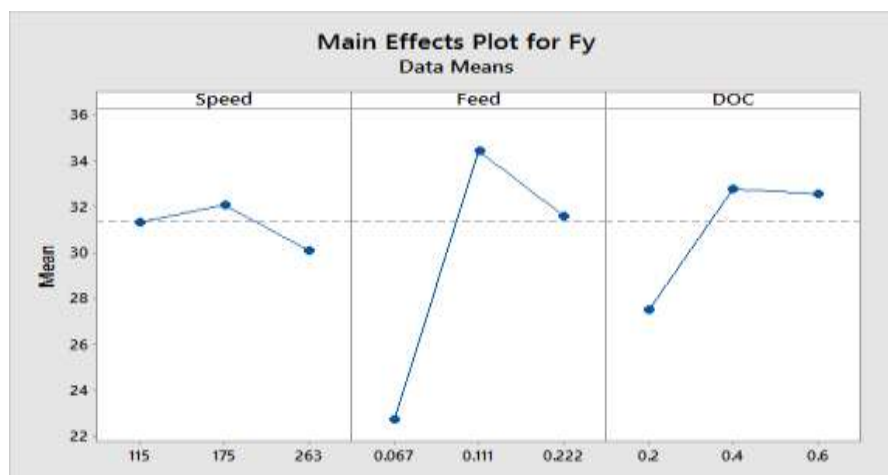


Figure: 5

Table: 7

S	R-sq	R-sq(adj)	R-sq(pred)
6.08950	71.52%	45.88%	0.00%

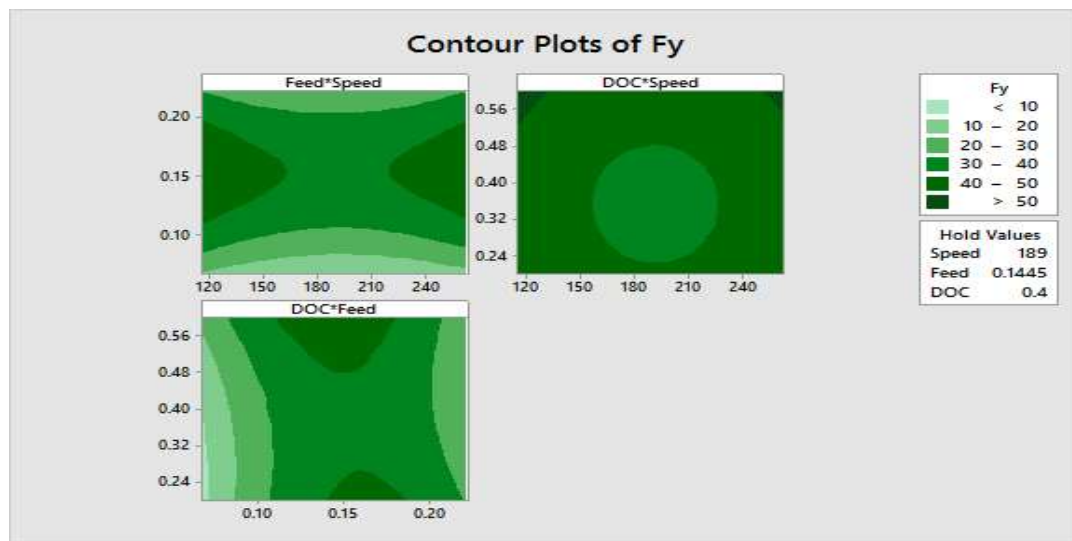


Figure: 6

Regression Equation in Uncoded Units

$$F_y = -0.1 - 0.579 \text{ Speed} + 1273 \text{ Feed} - 26.2 \text{ DOC} + 0.001474 \text{ Speed*Speed} - 3741 \text{ Feed*Feed} \\ + 108.6 \text{ DOC*DOC} + 0.106 \text{ Speed*Feed} - 0.001 \text{ Speed*DOC} - 348 \text{ Feed*DOC}$$

Coded Coefficients

Table: 8

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		10.804	0.799	13.52	0.000	

Speed	-0.005	-0.002	0.593	-0.00	0.997	1.03
Feed	5.944	2.972	0.646	4.60	0.001	1.24
DOC	1.763	0.881	0.594	1.48	0.169	1.01
Speed*Speed	6.61	3.31	1.27	2.61	0.026	2.14
Feed*Feed	-14.06	-7.03	1.84	-3.82	0.003	3.17
DOC*DOC	3.70	1.85	1.22	1.52	0.160	2.12
Speed*Feed	0.224	0.112	0.647	0.17	0.866	1.02
Speed*DOC	-0.019	-0.010	0.658	-0.01	0.989	1.00
Feed*DOC	-1.165	-0.583	0.648	-0.90	0.390	1.01

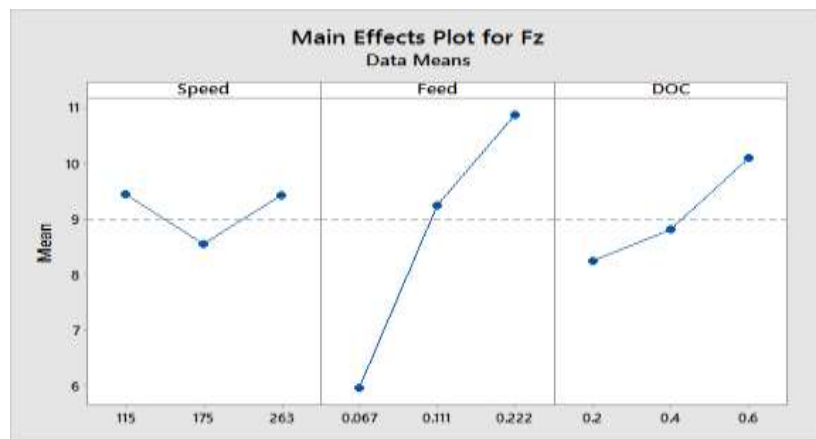


Figure: 7

Table: 9

S	R-sq	R-sq(adj)	R-sq(pred)
1.86778	75.15%	52.78%	0.00%

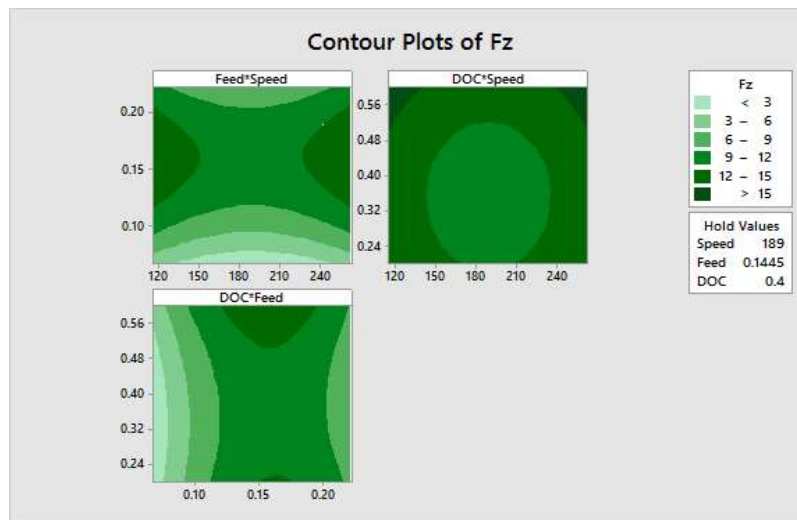


Figure: 8

Regression Equation in Uncoded Units

$$F_z = 6.34 - 0.2308 \text{ Speed} + 387.9 \text{ Feed} - 27.0 \text{ DOC} + 0.000604 \text{ Speed*Speed} - 1170 \text{ Feed*Feed} + 46.2 \text{ DOC*DOC} + 0.019 \text{ Speed*Feed} - 0.0006 \text{ Speed*DOC} - 37.6 \text{ Feed*DOC}$$

Coded Coefficients

Table: 10

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		4.085	0.161	25.36	0.000	
Speed	-0.877	-0.438	0.120	-3.67	0.004	1.03
Feed	2.455	1.227	0.130	9.43	0.000	1.24
DOC	0.017	0.008	0.120	0.07	0.946	1.01
Speed*Speed	2.010	1.005	0.255	3.94	0.003	2.14

Feed*Feed	-1.814	-0.907	0.371	-2.45	0.034	3.17
DOC*DOC	0.604	0.302	0.245	1.23	0.247	2.12
Speed*Feed	-0.381	-0.191	0.130	-1.46	0.175	1.02
Speed*DOC	-0.555	-0.277	0.133	-2.09	0.063	1.00
Feed*DOC	-0.257	-0.129	0.131	-0.98	0.348	1.01

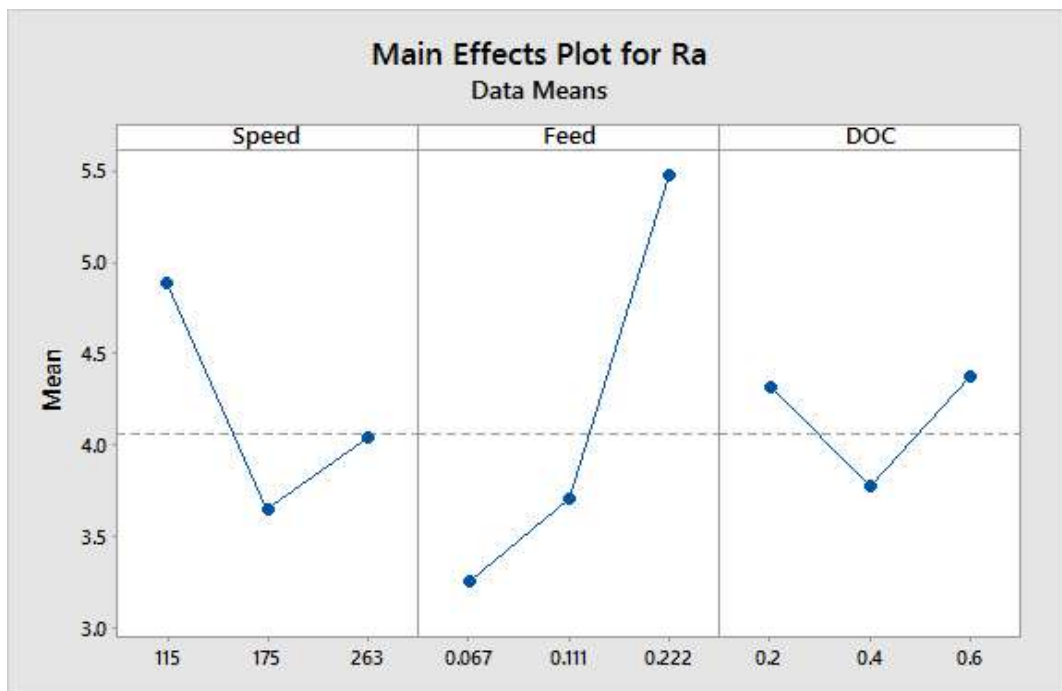


Figure: 10

Table: 11

S	R-sq	R-sq(adj)	R-sq(pred)
0.376427	93.15%	86.98%	15.20%

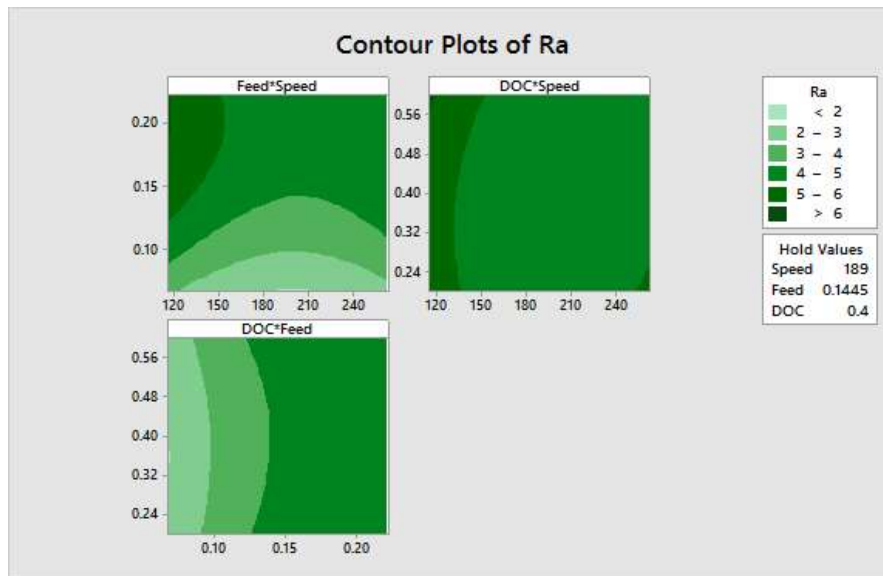


Figure: 9

Regression Equation in Uncoded Units

$$\begin{aligned} Ra = & 4.71 - 0.0630 \text{ Speed} + 69.1 \text{ Feed} - \\ & 1.25 \text{ DOC} + 0.000184 \text{ Speed*Speed} - \\ & 151.0 \text{ Feed*Feed} \\ & + 7.54 \text{ DOC*DOC} - 0.0332 \text{ Speed*Feed} - \\ & 0.01874 \text{ Speed*DOC} - 8.30 \text{ Feed*DOC} \end{aligned}$$

CONCLUSION

The feed rate has significant influence on both the Cutting force and Surface roughness. Cutting Speed has no significant effect on the cutting force as well as the surface roughness of the chosen work piece. Depth of cut has a significant influence on cutting force, but an insignificant influence on surface roughness. In turning process optimization with respect to power consumption, the focus should be on choosing an appropriate combination of feed rate and

depth of cut. Optimum surface roughness can be achieved by selecting relatively higher values of speed (>450 rpm), higher values of depth of cut (>0.75mm), and relatively lower values of feed rate (<0.11 mm/rev). In comparison to the sequential approach adopted in most of the contemporary research, this research has shown that adjusted approach can also be successfully used to fit a reasonably acceptable and generalized model provided, it is a mono-block design. While the results declared through this experimental work may be generalized to a considerable extent while working on EN8 steel using HSS tool, the study is limited to the extreme range of values of the cutting parameters specified. Future research work may be directed towards applying Response Surface Methodology

to further fine tune the optimization of cutting parameters, which was beyond the scope of this research, as it was mainly focused towards the identification of most significantly influencing factors.

The effect of machining parameters speed, feed, depth of cut, are studied on surface roughness for face turning operation using EN-8. Regression Analyses (RA) technique is used to study the effect of these parameters and their interaction on surface roughness. An empirical equation is formed by using Regression Analyses (RA) in Mini-Tab software to predict the surface roughness. The surface roughness model produced during this research work may be used in enhancing the surface quality of a product as cutting parameters are optimized and can give better surface finish.

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