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Analysis of Forces & Surface Roughness on Hardened Steel With Uncoated Ceramic Insert Using Taguchi Technique.

Dadapeer.B[1], Dr. C. K.Umesh[2]

[1]*Associate professor, Department of Mechanical Engineering, AMC Engineering College, Bengaluru, Karnataka, India*
[2]*Associate professor, Department of Mechanical Engineering, UVCE, Bengaluru, Karnataka, India*

***Abstract*— The objective of this paper is to analyze the influence of various turning process parameters such as cutting speed, feed rate and depth of cut on the Feed force, Tangential force & Surface roughness while machining hardened EN-353 steel with uncoated ceramic insert. The effect of the selected process parameters on the Feed force (F_X), Tangential force (F_Y) and Surface roughness (R_a) have been accomplished using Taguchi's design of experiments approach. The results indicate that the selected process parameters significantly affect the mean & variance of Feed force, Tangential force and Surface roughness. The percent contributions of parameters in the ANOVA table for Feed force (F_X) for the depth of cut (87.99%) has a major contribution than that of feed rate (2.82 %) and the cutting speed (4.45%). Tangential force (F_Y), the depth of cut (81.56%) has a major contribution than that of cutting speed (3.8%) and feed rate (9.87%). Similarly the Surface roughness (R_a), has depth of cut (59.59%) has a major contribution than that of cutting speed (23.67%) and feed rate (4.64%). In all these cases the interactions are not having any major contributions.**

***Keywords*—Cutting force, Feed force, Surface roughness, uncoated Ceramic tool and ANOVA.**

I. INTRODUCTION

The metal cutting industries in developing countries continue to suffer from a major drawback of not running the machine tools at their operating conditions. The operating conditions continue to the chosen solely on the basis of the handbook values and or work experience. The literature survey has revealed, a little research has been conducted to obtain the machining characteristics of cutting parameters- cutting speed, feed rate, and depth of cut

Hari singh and Pradeep Kumar [1] constructed an Ishikawa cause-effect diagram in order to identify the process parameters that may affect the machining characteristics of turned parts such as cutting tool parameters- Tool geometry and Tool material; workpiece related parameters – metallographic hardness etc., cutting parameters- cutting speed, feed rate and depth of cut, dry cutting and wet cutting. Thamizhmanii S. et al. [2] found that the surface roughness from various tests shows a decrease in values at higher cutting speeds and feed rates.

The cutting tool has produced micro chipping and has not affected the surface finish. Yoichi Matsumoto and Da-Chun Hsu [3] have performed the work piece temperature rise study during the cutting of AISI 4340 steel, that temperature rises in work piece were measured during the cutting of various hardness of steel by a ceramic tool. Thermocouples were embedded in a specially designed work piece for the temperature measurement. The temperature increase in the work piece is quite low when a ceramic tool is used to cut steels of various hardness. The penetration of heat becomes deeper as the cutting speed slows down. P.Munoz – Escalona, Z. Cassier et.al. [4] have studied the influence of the critical cutting speed on the surface finish of turned steel. Variables such as feed rate and the tool nose radius and cutting speed can provide a control on the quality and the surface finish in a given machining process. Singh and Kumar [5] studied on optimization of feed force through setting of optimal value of process parameters namely cutting speed, feed rate and depth of cut in turning of EN-24 steel with TiC coated Tungsten carbide inserts. The authors used Taguchi's parameters design and concluded that the effect of depth of cut and feed variations of feed force affected more as compared to speed. Sahoo et. al. [6] studied for optimization of machining parameters combinations emphasizing on fractal characterstics of surface profile generated in CNC turning operation. The authors used L_{27} Taguchi orthogonal array design with machining parameters: cutting speed, feed rate and depth of cut on three different workpiece materials namely Aluminium, Mild steel and Brass. It was concluded that feed rate was more significant in influencing surface finish in all three materials. S. Lo Casto. [7] used wear rates and wear mechanisms of alumina based tool cutting steels at a low cutting speed. Three ceramic insert materials, Zirconia-toughened (Al_2O_3 -7 vol% ZrO_2), mixed based alumina (Al_2O_3 – TiN – TiC – ZrO_2) and alumina reinforced with SiC whickers (Al_2O_3 - SiCw), were used to cut AISI 1040 steel at 3.9m/s. in addition, a traditional grade P10 inserts (WC-TiC - Co) was rested. The worn zone was observed with scanning electron microscopy techniques.

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A. Bellosi et. al. [8] observed that the demand for TiC-based cermet tool inserts continues to grow and is now second to the WC-Co. this is due to excellent wear resistance and chemical stability at high temperatures. TiN nanopowder mixed with different metal carbides and binders are employed to produce TiC based cermets with TiN nanopowder addition. The binder forms a matrix where ceramic particles are dispersed, provided by ceramic particles, are combined toughness and thermal shock provided by the binder. G. Brandt et al [9] used crater wear of alumina based ceramic cutting tools when machining steel is predominantly dependent upon superficial plastic deformation. Such tool surface deformation may be greatly affected by chemical reactions with work piece materials. Crater surfaces of worn alumina based ceramic tools are coromant grade CC 620 (a pure ceramic, containing Al_2O_3 and ZrO_2) have been analyzed by electron microprobe and cathodoluminescence after turning steel SS 2541 (similar to AISI 4337). It has been found that the deformed surface layer had increased concentrations of iron and magnesium. Both these elements were probably present as spinal phases $FeO.Al_2O_3$ and $MgO.nAl_2O_3$ in solid solutions. Motorcu and Sahin [10] machined the hardened AISI 1040 steel with triangular and square tools in different machining conditions and modeled the surface parameters on surface roughness. They classified the effects of machining and cutting speed respectively. They stated that the lowest surface roughness is produced with square tools. S.Mittal et.al. [11] have recently been proven that it is feasible to use hard turning in selected conditions to surface finish, hardened to 64 HRC, to surface finish of 2 micro inches, thus making it possible to eliminate the need for separate grinding and abrasive-based super finish in a broad range of production activities involving hardened workpieces.

II. EXPERIMENTAL DETAILS

The heat treated EN-353 steel is selected as the work material for turning operation. The following process parameters were selected for the present work: cutting speed-(A), feed rate-(B), and depth of cut-(C), Tool material- uncoated ceramic insert (Kennametal Widia) make.

Insert geometry- MTJNR2020M12.
Tool holder- **MTJNR2020K16**.
Cutting conditions-Dry
Tool overhang-20 mm

Selection of an orthogonal array (OA):

In selecting an appropriate OA, the prerequisites are:

i) Selection of process parameters and interactions to be evaluated
ii) Selection of number of levels for the selected parameters.

The non-linear behavior of the process parameters if exists, can only be revealed if more than two level of the parameters along with their values at three levels are given in Table 1. It was also decided to study the two factor interaction effects on the cutting force [9]. The selected interactions were:

i) Between cutting speed and feed (AxB)
ii) Between feed and depth of cut (BxC)
iii) Between speed and depth of cut (AxC)

The three parameters each at three levels and three second – order interactions were selected and the total degree of freedom (DOF) required is 18, since a three level parameter has 2 DOF (number of levels – 1) and each second order interaction has 4 DOF (product of DOF of interacting parameters). As per Taguchi's method the total DOF of the selected OA must be greater than or equal to the total DOF required for the experiment. In this paper Taguchi's method approach is used to analyze the cutting forces, surface roughness and optimum cutting conditions for Feed force (Fx), Tangential force (Fy) and surface roughness (Ra) by considering the turning process parameters like cutting speed, feed and depth of cut using uncoated ceramic insert while machining EN-353 steel.

EN-353 steel rods of 60 mm diameter and 300 mm length were machined on HMT Lathe having power 3.5 KW using uncoated ceramic inserts having the designation **MTJNR2020M12**. The workpiece is machined as per the process parameters given in **Table 1.** The Feed force (Fx) & Tangential force (Fy) were measured for each trial using lathe tool dynamometer and the Surface (Ra) is measured using Talysurf. The Analysis of Variance (ANOVA) for raw data and Signal to Noise ratio are calculated for Feed force (F_x), Tangential force (F_y) and Surface roughness (R_a) and are tabulated in Table 3 to Table 8. The Signal – to – Noise ratio for LB characteristics are calculated using:

$$S/N_{LB} = -10 \log \left(\frac{1}{r}\sum_{i=1}^{r} y_i^2\right) \quad (1)$$

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TABLE 1
shows the details of the process parameters:

Process parameters	Parameters Designation	Levels		
		L1	L2	L3
Cutting speed (m/min)	A	101.78	131.94	171.53
Feed (mm/rev)	B	0.125	0.148	0.187
Depth of cut (mm)	C	0.05	0.10	0.20

The experiments are conducted as per the process parameters listed in Table 1, using Taguchi Technique L_{27} cycle.

TABLE 2
shows the details of experimental data of Feed force (F_X), Tangential force (F_Y) and Surface roughness (R_a) for L_{27}.

Sl. No	F_X N	F_Y N	R_a µm	S/N-F_X	S/N-F_Y	S/N-R_a
1	30	50	1.19	-29.54	-33.97	-1.43
2	90	90	1.25	-39.08	-39.08	-1.94
3	120	130	1.36	-41.58	-42.27	-2.67
4	20	80	1.01	-26.02	-38.07	-0.17
5	90	100	1.10	-39.08	-40	-0.82
6	120	160	1.30	-41.58	-44.08	-2.34
7	20	70	1.04	-26.02	-36.90	-0.25
8	110	110	1.25	-40.82	-40.82	-1.93
9	130	210	1.36	-42.27	-46.44	-2.67
10	50	70	1.24	-33.97	-36.90	-1.93
11	100	100	1.36	-40	-40	-2.60
12	130	160	1.5	-42.27	-44.08	-3.52
13	30	90	1.07	-29.54	-39.08	-0.50
14	100	120	1.16	-40	-41.58	-1.21
15	130	180	1.39	-42.27	-45.10	-2.8
16	40	90	1.11	-32.04	-39.08	-0.90
17	130	130	1.35	-42.27	-42.27	-2.60
18	150	230	1.45	-43.52	-47.23	-3.22
19	30	50	1.05	-29.54	-33.97	-0.42
20	90	90	1.15	-39.08	-39.08	-1.21
21	90	150	1.26	-39.08	-43.52	-2.07
22	20	60	0.96	-26.02	-35.56	-0.45
23	90	100	1.08	-39.08	-40	-0.66
24	90	160	1.3	-39.08	-44.08	-2.28
25	30	70	0.90	-29.54	-36.90	-0.91
26	90	110	1.07	-39.08	-40.82	-0.50
27	140	210	1.2	-42.92	-46.44	-1.63

TABLE 3
shows ANOVA results for Feed force (F_X).

Factor	DOF	SS	MSS	Fcal	Ftab confidence level			P= (SS/SS$_T$)* 100
					90%	95%	99%	
A	2	2096.2	1048.1	53.39	3.11	4.46	8.65	4.45%
B	2	1340.7	670.37	34.14	3.11	4.46	8.65	2.82%
C	2	41385	20692	1054	3.11	4.46	8.65	87.99 %
AxB	4	125.92	31.48	1.60	2.81	3.84	7.01	0.26%
BxC	4	903.70	225.92	11.50	2.81	3.84	7.01	1.92%
AxC	4	348.14	87.03	4.43	2.81	3.84	7.01	0.74%
Error	8	19.63	2.45					1.82%
Total	26	47029						100%

TABLE 4
shows ANOVA results for Signal to Noise ratio (S/N) for Feed force (F_X).

Factor	DOF	SS	MSS	Fcal	Ftab confidence level			P= (SS/SS$_T$)* 100
					90%	95%	99%	
A	2	33.60	16.80	2.146	3.11	4.46	8.65	3.8%
B	2	15.29	7.648	0.977	3.11	4.46	8.65	1.67%
C	2	820.49	410.2	52.41	3.11	4.46	8.65	90.02%
AxB	4	2.17	0.543	0.069	2.81	3.84	7.01	0.23%
BxC	4	17.72	4.431	0.566	2.81	3.84	7.01	1.94%
AxC	4	14.32	3.582	0.457	2.81	3.84	7.01	1.56%
Error	8	7.82	0.978					0.84%
Total	26	911.44						100%

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TABLE 5
shows ANOVA results for Tangential force (F_Y).

Factor	DOF	SS	MSS	Fcal	Ftab confidence level			P= (SS/SS$_T$)* 100
					90%	95%	99%	
A	2	2140.7	1070	6.57	3.11	4.46	8.65	3.28%
B	2	6429.6	3214	19.75	3.11	4.46	8.65	9.87%
C	2	53096	26548	163.1	3.11	4.46	8.65	81.56%
AxB	4	148.14	37.03	0.22	2.81	3.84	7.01	0.22%
BxC	4	2992.5	748.1	4.59	2.81	3.84	7.01	4.59%
AxC	4	148.14	37.03	0.22	2.81	3.84	7.01	0.22%
Error	8	162.72	20.34					0.25%
Total	26	65118						100%

TABLE 6
shows ANOVA results for Signal to Noise ratio (S/N) for Tangential force (F_Y).

Factor	DOF	SS	MSS	Fcal	Ftab confidence level			P= (SS/SS$_T$)* 100
					90%	95%	99%	
A	2	15.25	7.62	19.414	3.11	4.46	8.65	4.29%
B	2	27.70	13.85	35.468	3.11	4.46	8.65	7.80%
C	2	295.3	147.6	375.72	3.11	4.46	8.65	83.19%
AxB	4	295.3	1.54	3.93	2.81	3.84	7.01	1.74%
BxC	4	6.17	2.51	6.39	2.81	3.84	7.01	2.83%
AxC	4	10.05	0.89	2.28	2.81	3.84	7.01	1.01%
Error	8	3.14	0.39					0.88%
Total	26	354.9						100%

TABLE 7
shows ANOVA results for Surface roughness (R_a).

Factor	DOF	SS	MSS	Fcal	Ftab confidence level			P= (SS/SS$_T$) * 100
					90%	95%	99%	
A	2	0.146	0.07	4.537	3.11	4.46	8.65	23.67%
B	2	0.057	0.02	1.295	3.11	4.46	8.65	4.64%
C	2	0.367	0.18	11.41	3.11	4.46	8.65	59.59%
AxB	4	0.020	0.05	3.149	2.81	3.84	7.01	3.29%
BxC	4	0.209	0.05	3.242	2.81	3.84	7.01	3.38%
AxC	4	0.017	0.14	0.274	2.81	3.84	7.01	2.86%
Error	8	0.012	0.01					2.56%
Total	26	0.617						100%

TABLE 8
shows results for the Signal to Noise ratio (S/N) for Surface roughness (R_a).

Factor	DOF	SS	MSS	Fcal	Ftab confidence level			P= (SS/SS$_T$) * 100
					90 %	95%	99%	
A	2	8.05	4.02	276.4	3.11	4.46	8.65	23.6 %
B	2	3.17	1.58	109.0	3.11	4.46	8.65	9.34%
C	2	19.9	9.98	685.4	3.11	4.46	8.65	58.61%
AxB	4	1.18	0.29	20.36	2.81	3.84	7.01	3.48%
BxC	4	1.47	0.36	25.29	2.81	3.84	7.01	4.32%
AxC	4	0.09	0.02	1.613	2.81	3.84	7.01	0.28%
Error	8	0.11	0.01					0.35%
Total	26	34.0						100%

III. Result And Discussion

From Table 3, the ANOVA from Feed force (F_X) for confidence level of 90%, 95% and 99%, it is observed that depth of cut has a significant percent contribution (87.99%) compared to the feed rate (4.45%) and cutting speed (2.82%).The Signal to Noise ratio for Feed force (F_X) also exhibits similar trend and these are tabulated in Table 4. However there is no much major contribution from the interactions (AxB), (BxC), (AxC) and error respectively.

From Table 5 Tangential force (F_Y) for confidence level of 90%, 95% and 99%, it is observed that the depth of cut has a significant percent contribution (81.56%) compared to feed rate (9.87%) and cutting speed (3.28%). The Signal to Noise ratio for Tangential force (F_Y) also exhibits similar trend and these are tabulated in Table 6. However there is no much major contribution from the interactions (AxB), (BxC), (AxC) and error respectively.

From the Table 7 the ANOVA for surface roughness (R_a) for confidence level of 90%, 95% and 99%, it is observed that depth of cut has a significant percent contribution (59.59%), compared to cutting speed (23.67%) and feed rate (4.64%). The Signal to Noise ratio for Surface roughness (R_a) also exhibits similar trend and these are tabulated in Table 8. However there is no much significant contribution from the interactions (AxB), (BxC), (AxC) and error respectively.

IV. Conclusion

- The depth of cut is having a significant percent contribution in the Feed force (F_X), Tangential force (F_Y) and Surface Roughness (R_a).
- From the ANOVA table for Feed force, Tangential force & Surface Roughness for 90%, 95% and 99% confidence level, there is no change in percent contribution except for the F-tabulated values. As the confidence level increases the F-tabulated values also increases. However there is no much significant contribution from the interactions (AxB), (BxC), (AxC) and error respectively. The S/N ratio for Feed force, Tangential force and Surface roughness for L_{27} also exhibits similar trends and these are tabulated in Table 4, 6 and 8 respectively.

REFERENCES

[1] Hari Singh and Pradeep Kumar, "Quality optimization of turned parts (EN-24 steel) by Taguchi method productivity journal, vol.44, No.1, April – June 2003, pp.43 – 49.

[2] Thamizhmanii S. "Tool Flank Wear Analyses on Martensitic Steel by Turning". International Scintific Published monthly by the Wold Academy of Material and Manufacturing Engineering. Vol.32 july 2008, page -41-44.

[3] Yoichi Matsumoto and Da-Chun Hsu "Performed the workpiece temperature rise during cutting of AISI 4340 Steel". Wear, 116(1987)309-317.

[4] P.Munoz – Escalona, Z. Cassier –"The influence of the critical cutting speed on the surface finish of turned steel". Wear 220(1998)21-33

[5] Singh.H. and Kumar. P. "Optimizing feed force for turned parts through the Taguchi Technique", Sadhana (2006), vol.31, No.6, pp. 671 – 681.

[6] Sahoo P, Barman T.K. and Routasa B.C, "Taguchi based practical dimension modeling and optimization in CNC turning", Advance in Production Engineering and Management (20008), vol. 3, No.4, pp. 205 – 217.

[7] S. Lo Casto-"Wear rates and Wear meachanism of Alumina-base tools cutting steel at a low cutting speed". Wear 208(1997)62-67.

[8] A.Bellosi, R.Calzavarini, Faga M.G.Monteverde, "Characterization and application of Titanium Carbonitide-based cutting tools". J.Mater Process Technol.143(2003)527-532.

[9] G. Brandt and M.Mikus, "An electron microprobe and cathodoluminescence study of chemical reactions between tool and workpiece when turning steel with alumina-based ceramics", Wear 115(1987)243-263.

[10] Motorcu AR., Sahin Y.Modeling of surface roughness in the machinability of hardened low carbon AISI 1040 steel with different geometry coated carbide insert. In: Proceeding of the 4th International advanced technologies symposium 28 – 30 september p. 860 – 865.

[11] S.Mittal, C.R. Liu, "A Method of Modeling Residual Stresses in Superfinish Hard Turning". Wear 218(1998)21-33.