

An Investigation of Forces, Surface Roughness and Chip Morphology of En 19 Material during Turning

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ABSTRACT:The qualitative and quantitative requirement of customer is frequently change so the demand of the hour is increasing. Maintaining the economic production with optimal use of resources is of prime concern for the engineers. Metal machining is one of them. Some challenges that the engineers come across are to find out the optimal parameters for the desired product quality and to maximize the performance of manufacturing using the available resources. Turning is a very important machining process in which a single-point cutting tool removes material from the surface of a rotating cylindrical work-piece.. In this study the effect of change in different process parameters (cutting speed, feed and depth of cut) on different performance evaluation criteria (cutting force, surface roughness and chip formation) have been investigated. So, it has been decided to characterization of EN19 steel with use of low cost HSS tool on CNC and it will measure cutting forces, surface roughness and tool wear for EN19 steel using HSS tool bit on CNC.

KEYWORDS: Turning, Cutting force, Surface roughness, GRA, Regression analysis.

I. INTRODUCTION

Turning is a very important machining process in which a single-point cutting tool removes material from the surface of a rotating cylindrical work-piece. Three cutting parameters, i.e., cutting speed (v), feed rate (f), and depth of cut (d), should be properly selected for performance evaluation criteria such as surface finish, lower temperature at cutting zone, less tool wear and long tool life etc. Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece to a specified dimension, and to produce a smooth finish on the work-piece. Often the work piece will be turned so that adjacent sections have different diameters.

Dinesh G. Thakur et al (2011) have been shown that cryogenic post treatment improved the tool life of tungsten carbide tool. They show that the degree of work hardening can be minimized by properly selecting the cutting parameters and Tool flank wear was found to be more uniform in the case of cryogenic post treated tungsten carbide tool than untreated tungsten carbide tool and residual stresses were found to be 7% less in cryogenic post treated tool than untreated tool.^[9] Yigit Kazancoglu Ugar Esme et al(2011) has been found that feed rate was to be the major factor affecting the material removal rate, the cutting force and the surface roughness (48.63%), whereas the depth of cut (26.71%) and cutting speed (17.81%).^[13] J. Paulo davim, V.N. Gaitonde et al (2009) have been planned as per full factorial design (FFD) and the adequacy of the models has been tested through analysis of variance (ANOVA) Based on the experimental results and parametric analysis. It has been found that CC650WG wiper ceramic insert is perform better in reference of surface roughness and tool wear while CC650 is better in minimizing of machining force, power and specific cutting force.^[11] Ay Mustafa et al (2010) were found the percentage of influence of various factors and their interaction on turning.^[18] Abhijit S. More et al (2006) shows that the cBN–TiN coated carbide tools are capable of reducing machining costs so it's suitable for hard turning.^[4] Giovanni R. dos Santos, Dalberto D.da et al (2007) reported that the reduction of cutting force is 6% when machining the alloy with 12% wt silicon and in case of machining the alloy with 16wt% of silicons, the reduction of cutting force is around 4% so cutting force shows minor difference for both aluminium and silicon alloy.^[3] J.Hu, Y.K. Chou et al (2007) to study the stress modifications in diamond coating tools after the depositions and during machining at different conditions.^[2] J.V.C. Souza et al (2008) have been show that the cutting forces is reduced after cutting speed of 300 m/min and the low tool wear of the inserts

suggests that Si3N4 is best for machining gray cast iron average temperature is reduced at same speed and higher the feed rates.^[5] Jeffrey Thiele et all (1999) have been found that the cutting edge geometry has a significant effect on the axial and radial cutting force components (or the equivalent thrust force), and that the effect of work piece hardness on the force components was found to be significant mainly for the 93.98 and 121.92 mm edge hones.^[7] Suleyman Yaldiz et all (2007), reported to comparison of experimental results obtaining from dynamometer to fuzzy model for predicting cutting forces in turning. The developed fuzzy model consisting of 27 rules for the prediction of the cutting forces in turning and they made this model only for steels. It have been found that the difference between experimental and calculated results is about 99.6%.^[7] A.K. Dutta et all (2006), has been showing that cutting forces of ZTA and Ag-10 inserts has much less differences. Thus to achieve the best performance, the amount of silver in the composites needs to be optimized.^[6] G. petropolus a et all (2005), showed that the highest influence on cutting force is exerted by the depth of cut and the feed of varying rder of contribution for every force components.^[22] Young huang et all (2003), carried out experiment turning operation of hardened 52100 steel with use of CBN insert. They measured forces with vary depth of cut, feed rates (0.0762 and 1.778 mm/rev) without considering the Ploughing effects with shallow cuts with large negative rake angle and large nose radius. Comparison of experimental result and model prediction result give difference 15%.^[12] Ilhan Astilurk et all (2011), determine the effect of cutting parameters on surface roughness in hard turning using the Taguchi method. They determined optimum cutting parameter s for minimum surface roughness. Results of that study indicate that the feed rate is the most significant effect on R_a and R_z .^[15] M. Kaladhar et all (2003), conducted experiments on AISI 304 austenitic stainless steel had determined surface roughness and material removal rate and revealed that the feed and nose radius are the most significant process parameters on the work materials for surface roughness.^[16] Adeel H. Suhail et all (2010), carried out experimental work on medium carbon steel AISI 1020 with use of CNMG432 TT5100 insert. It have been revealed that better surface finish at lower feed rate and highest cutting speed.^[17] A. Esteves Correia et all (2011) have been showed that at lower feed rate surface roughness are same in both cases but at higher feed rate, surface roughness is higher in conventional than wiper insert.^[19] Hardeep singh et all (2011) have been showed that the spindle speed contributed 64% and depth of cut 12% and feed rate 9% for surface roughness. The contribution for feed and RPM was 61% and 29% for material removal rate that feed rate.^[20] Erry Yulian et all (2009) showed that at low speed cutting speed life of cermet tool is quiet long and the surface finish is satisfactory and at a low negative rake angle the tool wear is less but at more negative rake angle, tool wear is high and also increase cutting forces and heat.^[21] Yusuf sahin et all (2005) developed surface roughness predication model can be effectively used to predicate the surface roughness which are makeable saving and cost.^[23] Jing Shi et all (2006) simulated by the proposed model, and their morphology and dimensions are consistent with those of the chips obtained from actual machining and the area of the chip in FE model for phase transformation match with actual chips.^[10] It has been found there is very few work for EN19 steel with different cutting tool material. In present study, it has been decided to use EN19 steel with HSS tool bit. In this study the effect of change in different process parameters (cutting speed, feed and depth of cut) on different performance evaluation criteria (cutting force, surface roughness and chip formation) have been investigated.

II. METHODOLOGY

FULL FACTORIAL DESIGN is used for simultaneous study of several factor effects on the process. By varying levels of factors simultaneously we can find optimal solution. Responses are measured at all combinations of the experimental factor levels. The combination of the factor levels represent the conditions at which responses will be measured. Each experiment condition is a run. The response measurement is an observation. The entire set of run is a design of experiment. It is used to find out the variables which are the most influence on the response and their interactions between two or more factors on responses. There is the three cutting process parameter selected.

Table 1 Range of process parameter

Control factor	Unit	Level		
		1	2	3
Feed (f)	mm/rev	0.05	0.10	0.15
Cutting speed (v)	m/min	30	49	68
Depth of cut (d)	Mm	0.5	0.75	1

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In the present study, the cutting process parameters have been selected on the basis of literature review, recommended data with cutting tool and machining data book. The range of selected process parameters are shown in table 1.

GREY RELATIONAL ANALYSIS, a grey relational grade can be obtained to evaluate the multiple performance characteristic. Then we get, optimization of the complicated multiple performance characteristic can be converted into the optimization of a single grey relation grade.

REGRESSION MODEL, determine how the response variable changes as particular predictor variable changes. Predict the value of the response variable for any value of the predictor variable, or combination of values of the predictor variables.

III. EXPERIMENTAL RESULTS

ANALYSIS OF VARIANCE FOR CUTTINGFORCE, According to the analysis done by the MINITAB software, if the values of probability are less than 0.05, it indicated that the factors are significant to the response parameters. Comparing the p-value to a commonly used α - level = 0.05, it is found that if the p- value is less than or equal to α , it can be concluded that the effect is significant, otherwise it is not significant

Table 2 Analysis of Variance for Cutting Force

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	11204	12204	6102	2.56	0.102
DOC	2	18472	18472	9236	3.88	0.038
Feed	2	502663	502663	251331	105.51	0.000
Error	20	47641	47641	2382		
Total	26	580979				
R-Sq = 92.79%				R-Sq (adj) = 89.34%		

From ANOVA result it is observed that the feed and depth of cut influencing parameter for cutting forces, while the value of p for cutting speed is 0.102 which is greater than 0.05 p value so they are not influencing parameter for cutting force. The confidence level (CL) used for investigation is taken 95% for this investigation. The parameter R-Sq described the amount of variation observed in cutting forces is explained by the input factor. R-Sq= 92.79% which indicate that the model is able to predicate the response with high accuracy.

ANALYSIS OF VARIANCE FOR FEED FORCE, From ANOVA result it is observed that the feed rate and cutting speed influencing parameter for feed forces, while the value of p for depth of cut is 0.133 which is greater than 0.05 p value. So, it is not influencing parameter for feed force.

Table 3 Analysis of Variance for feed force

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	117075	117075	58537	14.35	0.000
DOC	2	18203	18203	9101	2.23	0.133
Feed	2	153548	153549	76774	18.82	0.000
Error	20	81583	81583	4079		
Total	26	370409				
R-Sq = 81.97%				R-Sq(adj) = 76.37%		

The confidence level (CL) is taken 95% for this investigation. The parameter R-Sq described the amount of variation observed in feed force is explained by the input factor. R-Sq= 81.97% which indicate that the model is able to predicate the response with high accuracy.

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ANALYSIS OF VARIANCE FOR SURFACE ROUGHNESS, From ANOVA result it is observed that the feed rate and cutting speed are influencing parameter for Surface roughness, while the value of p for depth of cut is 0.234 which is greater than 0.05 p values. So, it is not influencing parameter for Surface roughness.

Table 4 Analysis of Variance for surface roughness

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Speed	2	3.7373	3.7373	1.8687	8.12	0.003
DOC	2	0.7191	0.7191	0.3595	1.56	0.234
Feed	2	17.7770	17.7770	8.8885	38.65	0.000
Error	20	4.5998	4.5998	0.2300		
Total	26	26.8332				
R-Sq = 82.86%			R-Sq(adj) = 77.72%			

The confidence level (CL) is taken 95% for this investigation. The parameter R-Sq described the amount of variation observed in cutting forces is explained by the input factor. R-Sq= 82.86% which indicate that the model is able to predicate the response with high accuracy.

GREY RELATIONAL ANALYSIS, The mean of grey relational grade for each level of the machining parameters is summarized and shown in following table 5.

Table 5 Main effect of factors on Grey Relational Grade

Symbol	Control Factor	Level-1	Level-2	Level-3
A	Speed	0.5300	0.5911	0.6678
B	DOC	0.6278	0.5933	0.5678
C	Feed	0.8156	0.5455	0.4278

As we know that higher grey relational grade value will give optimum value of cutting forces, feed forces and surface roughness. So from above table 5, it is concluded that level-3 is higher for cutting speed and level-1 is higher than for feed and as well as depth of cut. Thus it is revealed that response will be optimum at cutting speed 68 m/min, feed 0.05 mm/rev and depth of cut 0.50 mm.

REGRESSION ANALYSIS

$$\text{Cutting force} = -123 + 1.78A + 267B + 6834C - 3.74 AB - 4493BC - 77.7CA + 100ABC$$

$$\text{Feed force} = -447 + 7.63A + 491B + 7745C - 6.86AB - 3491BC - 116CA + 65.3ABC$$

$$\text{Surface roughness} = -4.84 + 0.105A + 6.59B + 79.1C - 0.137AB - 61.8BC - 1.11CA + 1.13ABC$$

The co-efficient of determination (R-Sq) indicates the goodness of fit for model. The R-Sq value for cutting force and feed force is 93.5 % and 91.00% which is indicates that model is fit for prediction. The R-Sq value for surface roughness is 88.6 % which is quiet high; therefore model is suitable for result prediction.

IV. CONFIRMATION TEST

The conformation test is the final step of this experimentation. The purpose of conformation test is to validate the conclusion drawn during the analysis phase. In addition, the conformation test needs to be carried out in order to ensure that the theoretical predicted model for optimum results using the software is accepted and in order to verify adequacy of the models that are developed. Here the orthogonal array, grey relational analysis and regression mathematical model optimize the same level, A3 B1 C1. Thus 25 number of combination of experimental run is give minimum response and not need to verify through experiment because of it is already done through full factorial design. So, it is

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concluded that this level or parameters value gives the best results for minimum cutting force, feed force and surface roughness.

V. CONCLUSION

The EN-19 has been turned with HSS tool bit. The conclusions relevant to this investigation are outlined below:

1. The cutting forces increase with increase feed from 0.05 to 0.15 mm/rev, when the other two parameter are kept constant as well as cutting force increase with increase depth of cut 0.50 to 1.00 mm, but reversely in case of cutting speed and vice versa.
2. The feed forces increase with increase feed from 0.05 to 0.15 mm/rev, when the other two parameter are kept constant as well as cutting force increase with increase depth of cut 0.50 to 1.00 mm, but reversely in case of cutting speed and vice versa.
3. While studying the effect of the cutting parameters on the cutting force, it was observed that the effect of the cutting speed far outweighs the effect of the feed and the depth of cut, which are again roughly equal. The optimum condition for machining to reduce cutting force would be A3 B1C1. The cutting speed kept at 68 m/min, the feed kept at 0.05mm/rev and the depth of cut kept at 0.5 mm.
4. While studying the effect of the cutting parameters on the feed force, it was observed that both the cutting speed and the feed rate play equally important roles in the effect on the feed force. The role of the depth of cut given is not crucial to the same extent. The optimum condition for machining to reduce feed force would be A3 B1 C1 i.e., the speed kept at 68 m/min, the feed kept at 0.05 mm/rev and the depth of cut kept at 0.50 mm.
5. After all experiments, we observed that at all combination cutting forces are higher than feed forces.
6. While studying the effect of the cutting parameters on the surface roughness, it was observed that both the cutting speed and the feed rate play equally important roles in the effect on the feed force. The role of the depth of cut given is not crucial to the same extent. The optimum condition for machining to reduce surface roughness would be A3 B1 C1. The speed kept at 68 m/min, the feed kept at 0.05 mm/rev and the depth of cut kept at 0.50 mm.
7. The surface roughness increase with increasing feed from 0.05 to 0.15 mm/rev, when the other two parameter are kept constant.
8. At lower depth of cut 0.5 mm as speed increase, the surface roughness decreased, but at higher depth of cut there is not significant trend of surface roughness with change in cutting speed.
9. The effect of change in the depth of cut from 0.50 to 1 mm on average surface roughness is slightly raised.

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