

An investigation of flank wear during turning process through using taguchi L32

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Abstract — Now a day, the qualitative and quantitative requirement of customer is frequently change. Maintaining the economic production with optimal use of resources is of prime concern for the engineers. In this paper, the effect of cutting speed, feed rate, depth of cut on tool wear (tool life) tungsten carbide inserts was experimented and analyzed using analysis of variance (ANOVA) technique, and the cutting conditions for their maximum tool life were evaluated.

Keywords-Hastelloy X; Flank wear; taguchi L32; WC; Turning;

I. INTRODUCTION

Metal machining with various process parameters 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 workpiece. The cutting tool is fed linearly in a direction parallel to the axis of rotation. The turning is carried out on a lathe that provides the power to turn the work-piece at a given rotational speed and to feed the cutting tool at a specified rate and depth of cut. [1]

Therefore, three cutting parameters are listed below

- Cutting speed (v)
- Feed rate (f)
- Depth of cut (d)

It 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.

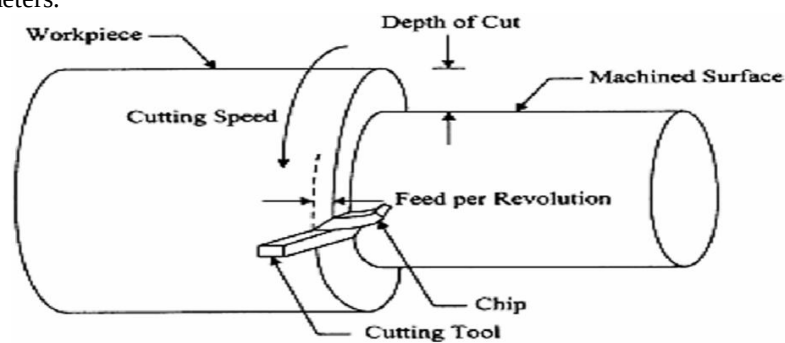


Figure 1.1 Schematic representation of the turning process [1]

Generally speaking, flank wear was caused by friction between the flank face of the tool and the machined surfaces. Tool wear depends on the tool, work piece material (physical, mechanical and chemical properties), tool geometry, cutting parameters, cutting fluid, etc. Flank wear generally attributed to rubbing of the tool with work piece at the interface, causing abrasive and/or adhesive wear and at high temperatures. Abrasion is the main wear mechanism in flank wear. BUE and irregular wear are often faced in machining stainless steels. At low cutting speed, the contact between work piece and flank of the tool was more and rubbing action continued for more time. The cutting zone temperature increases, this softens and decreases the strength of the BUE. Tool flank wear was strongly influenced by the interactions between cutting tool and work piece in the form of contact stress and cutting temperature. [4] As the cutting speeds and feed rates are increased, the rubbing action also faster and more heat produced even though less contact time exists. The generation of heat at flank side softens the edge and more wear occurred. The increase in cutting speeds wears the tool faster and

reduces the life of the tool. When the contact time was more at low speeds, the BUE formed which in turn act as another cutting edge.

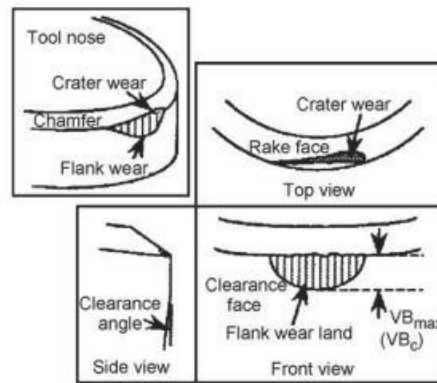


Figure 1.2 Typical wear in a single point tool turning [4]

II. LITERATURE REVIEW

V.N. Gaitonde et al. [6] have done machinability aspects the machining force (F_m), power (P), specific cutting force (K_s), surface roughness (R_a) and tool wear (VC) has been measured during hard turning of high chromium AISI D2 cold work tool steel with different CC650, CC650WG and GC6050WH ceramic inserts with linear increasing depth of cut. J.Hu et al. [7] reported the Nanocrystalline diamond coatings were produced using a microwave plasma-assisted CVD (chemical vapour deposition) process and deposited on common tungsten carbide tools. Giovanni R. dos Santos et al. [8] reported the deposition and characterization of a DLC thin film on a cemented carbide cutting tool was carried out. It was also analyzed its effects on the performance of turning tests for aluminum–silicon alloys with 12 wt. % and 16 wt. % of silicon. Abhijit S. More et al. [9] reported on Hard turning experiments based on full factorial design of experiments on hardened AISI 4340 steel ($HRC = 53$) using cBN–TiN coated inserts and commercially available PCBN (poly crystalline cubic boron nitride) inserts with vary cutting speed (100, 125 and 150 m/min) and a feed rate (0.10, 0.15 and 0.20 mm/rev) corresponding to a fixed depth of cut of 0.25 mm. J.V.C. Souza et al [10] reported to investigation about the effect of cutting forces on gray cast iron turning using silicon nitride (Si_3N_4) based ceramic tool. A.K. Dutta et al [11] reported to carried out experiment on turning of C45 steel using commercial zirconia toughened alumina (ZTA) inserts and developed inserts from composites of altering Ag_2O content as 5, 10 and 15wt%. Jeffrey D et al. [12] reported to a detailed experimental investigation into the effects of cutting edge preparation and work piece hardness on the surface finish and cutting forces in the finish hard turning of AISI 52100 steel using cubic boron nitride (CBN). S.A. Khan, S.L. Soo et al, [13] presented tool wear/life evaluation when finish turning Inconel 718 using PCBN tooling. Harsh Y Valera and Shanket N Bhavsar, [14] presented studied of surface roughness and power consumption in turning operation of en 31 alloy steel with $TiN+Al_2O_3+TiCN$ coated tungsten carbide tool under different cutting parameters. D. Philip Selvaraj, P. Chandramohan and M. Mohanraj, [15] presented of surface roughness, cutting force and tool wear of nitrogen alloyed duplex stainless steel in a dry turning process with TiC and TiCN coated carbide cutting tool inserts. Selim Gorgen, et al, [16] conducted experiment on optimization of turning operation of hardened EN24 steel with self-propelled rotary tool. They took various process Parameters such as horizontal inclination angle of the SPRT, depth of cut, feed rate and spindle speed for investigated on surface roughness (R_a) and metal removal rate. Nilrudra Mandal. et al, [17] conducted experiment on flank wear using Zirconia Toughened Alumina (ZTA) cutting tool on AISI 4340 steel using regression analysis. C. J. Rao, D. Sreemulu et al, [18] conducted experiments on tool life during turning operation by determining optimal process parameters. In this work aluminum is taken as a work material and tungsten carbide as tool material. N. Senthilkumar et al [19] conducted experiment on ‘Experimental investigation and performance analysis of cemented carbide inserts of different geometries using Taguchi based grey relational analysis’. Ilhan Asilturk, Harun Akkus, [20] presented the effect of cutting parameters on surface roughness in hard turning using the taguchi method. This study focuses on optimizing turning parameters based on the Taguchi method to minimize surface roughness. Kejia Zhuang et al [21] reported that the notch wear prediction model in turning of Inconel 718 with ceramic tools considering the influence of work hardened layer. A. K. Sahoo et al, [22] conducted experiment in development and machinability assessment in turning Al/SiCp-metal matrix composite with multilayer coated carbide insert using Taguchi and statistical techniques.

III. METHODOLOGY

3.1. Selection of machine tool

The machining test was carried out on a Anil CNC Turning Machines, Agile CNC. with compact design with low cost. The picture of the turning machine is shown in figure 3.1.



Figure 3.1CNC turning center (Photo Courtesy: S.P.B. Patel Engg College)

3.2. Selection of workpiece material

Specimen of Hastelloy X, were prepared with dimensions of diameter 16mm×40mm and then used for the experiments. The chemical composition and mechanical properties of the specimen are given in tables 1 and 2, respectively. As the content of the workpiece, chromium (22.14%) and molybdenum (9.24), are high, the material is hard to machine. The material consist of 49.51% nickel, making the alloy suitable for high-temperature application.

Table 1 Chemical composition of the workpiece material (Hastelloy X)

Contant	NI	CR	MO	FE	MN
Percent	49.51	22.14	9.27	18.19	0.47

Table 2 Mechanical properties of Hastelloy X

Hardness conductivity (HB)	Tensile strength(MPa)	Yield strength (MPa)	Breaking extension (%)
388	1370	1170	23.3

3.3. Selection of cutting tool

Standard grade WC with designation TNMG (KCU10 kennametal Inc.)



Figure 3.2Tungsten carbide insert

3.4. Selection of process parameters

The feed rate, cutting speed and depth of cut process parameters and their levels are arrived at based on the result of pre limiting experiments and the recommendations of the SUN India Company.

Table 3 Range of process parameter

Control factor	Unit	Level			
		1	2	3	4
Working condition		Wet	Dry		
Feed (f)	mm/rev	0.1	0.15	0.20	0.25
Cutting speed (v)	m/min	40	55	70	85
Depth of cut (d)	Mm	0.25	0.50	0.75	1

3.5. Design of Experiment

Design of experiment (doe) is a powerful statistical technique for improving product/process designs and solving production problems. A standardized version of the doe, as forwarded by Dr. Genichi Taguchi, allows one to easily learn and apply the technique product design optimization and production problem investigation. In the present investigation, S/N data analysis has been performed. The effects of the selected turning process parameters on the selected quality characteristics have been investigated through the plots of the main effects. The optimum condition for each of the quality characteristics has been established through S/N data analysis. The working levels of the input parameters are based on literature survey. Taguchi's L32Orthogonal Array (OA) has been selected. In the present experimental study, cutting velocity, feed, depth of cut and cutting condition will be considered as input parameters.

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.

IV. RESULTS AND DISCUSSION

ANALYSIS OF VARIANCE FOR FLANK WEAR, 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 4 ANOVA Table

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cutting condition	1	0.57781	0.57781	0.57781	29.26	0.000
Feed	3	1.24171	1.24171	0.41390	20.96	0.000
Speed	3	1.40781	1.40781	0.46927	23.76	0.000
DOC	3	0.18281	0.18281	0.06094	3.09	0.049
Error	21	0.41474	0.41474	0.01975		
total	31	3.82489				
S= 0.140533		R-Sq = 89.16%		R-Sq (adj) = 83.99%		

From ANOVA result it is observed that the cutting condition, speed and feed influencing parameter for flank wear, while the value of p for depth of cut is 0.049 which is near about same 0.05 p value so they are very slightly influencing parameter for flank wear. The confidence level (CL) used for investigation is taken 95% for this investigation. The parameter R-Sq described the amount of variation observed in flank wear is explained by the input factor. R-Sq= 89.16% which indicate that the model is able to predicate the response with high accuracy.

Main effect plots analysis

The analysis is made with the help of a software package MINITAB 16. The main effect plots are shown in fig.3. These shows the variation of response with the three parameters i.e. cutting condition, cutting speed, feed and depth of cut separately. In the plots, x axis indicate the value of each parameter at three level and y- axis the response value. Horizontal line indicates the mean value of the response. The main effects plots are used to determine the optimal design conditions to obtain the optimum flank wear.

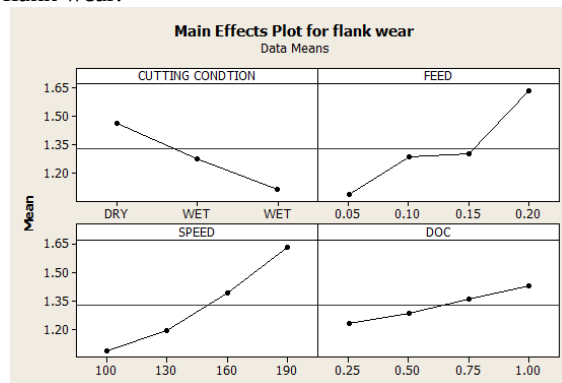


Figure 4.1 ANOVA graph

Fig.4.1 shows the main effect plot for surface roughness. According to this main effect plot, the optimal conditions for minimum flank wear are at cutting condition should be wet, cutting speed should be lower 100 m/min, feed rate 0.05 mm/rev and depth of cut at 0.25 mm.

The regression equation is

$$F_b = -0.0144 + 0.000617 \text{ SPEED} + 0.325 \text{ FEED} + 0.0270 \text{ DOC}$$

The co-efficient of determination (R-Sq) indicates the goodness of fit for model. The R-Sq value for flank wear is 81.5 % which indicates that model is fit for prediction. therefore model is suitable for result prediction.

V: CONCLUSION

This study discussed an application of the Taguchi L32 for optimizing the cutting parameters in turning operations performance measure flank wear. From this research, following conclusions could be reached with a fair amount of confidence:

Regardless of the category of the quality characteristic, for flank wear the cutting condition should be wet with cutting fluid which lead to dissipate heat which accumulated near cutting zone and provide cooling effect to tip of tool so it will increase tool life and reduce flank wear. Also lowest feed rate ($F = 0.05 \text{ mm/rev}$), the lowest cutting speed ($S = 100 \text{ m/min}$) and lowest depth of cut ($D = 0.25 \text{ mm}$) lead to optimal flank wear.

SCOPE FOR FUTURE WORK

In this present study only three parameters have been studied in accordance with their effects. View of future scope, other factors like Nose Radius, Coated HSS tool bit etc. can be studied. Also, the other outputs like power consumption, tool life, material removal rate etc. can be added.

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