Experimental Investigation for Nitride Ceramic Cutting Insert for Material Removal Rate on High Chrome Steel

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Abstract— A Present research paper study of literature survey on hard turning process in cutting parameter on cutting speed, feed and depth of cut on value in high chrome steel by using Nitride ceramic cutting tool insert. Three-factor (cutting speed, feed rate and depth of cut) completed with a statistical analysis of variance (ANOVA) were performed. Mathematical models for material removal rate developed using the Regression analysis (RA). Results show that the material removal rate components are principally by the depth of cut and work-piece on statistical significance. Finally, the ranges for best cutting conditions are proposed for serial industrial production optimum value in maximum material removal rate.

Key words: Hard Turning, Optimization, Design of experiment, ANOVA, Regression analysis, High chrome steel, nitride ceramic

I. Introduction

Hard turning process in which steel having hardness between50-65 HRC are turned to the near net shape eliminating the conventional process cycle. Nitride ceramic tools are widely used in the industry for cutting various hard materials such as die steels, bearing steels, case-hardened steels, white cast iron, and alloy cast irons[6]. In many applications, cutting of ferrous materials in their hardened condition can replace grinding to give significant savings in cost and productivity rates Advance cutting tool is precision, rough and high precision operation. Automated and flexible manufacturing systems are employed for that purpose along with computerized numerical control (CNC) machines that are capable of achieving high accuracy with very low processing time. The quality of surface is most significant for any product. In finishing operations, this enable a long tool life and close tolerance and results in shiny surfaces. The quality of the surface plays a very important role in the performance of dry/wet turning in CNC TC because a good quality turned surface surely improves fatigue strength, Corrosion resistance and creep life. In hard turning process by high chrome harden steel in using Drill Bits, Knives, Heavy machine parts, Gear, Metal Cutting Tools etc.

II. Literature Review

Sener Karabulut [1]: The best cutting combination for surface roughness was observed at A1B3 C1D3, i.e., with work piece material AA7039 reinforced with 10 wt.% Al2O3, cutting speed at 488 m/min, feed at 0.1 mm/tooth and axial depth of cut at 1 mm respectively effects of the cutting parameters on surface roughness and cutting force. The analysis results showed that material structure was the most effective factor on surface roughness and feed rate was the dominant factor affecting cutting force.

Shoujin Sun, Milan Brandt [2]: At a cutting speed of 150 m/min, the tool failure mode is flank wear. During cutting at a cutting speed of 220 m/min, the tool fails as a result of plastic deformation at the tool nose radius under dry cutting condition. The increase in tool life was more significant at higher cutting speed as the plastic deformation of cutting edge that occurred during dry machining was suppressed during machining with cryogenic compressed air cooling.

Wojciech Zebala, Robert Kowalczyk [3]: Cutting test was carried out on the distance 54 mm turning lentgh at the constant depth of cut 0.2 mm. The biggest increase of passive cutting force component Fp was indicated. The largest growth of the recorded cutting force was revealed for turning by insert with 0.4 mm nose radius. The increment of the cutting force for 54 mm turning length is almost 160%. The WC-Co turning process (with 25% Co content) with PCD tools with the maximal metal removal rate at the assumed limitations (e.g. maximal cutting forces).

Mohamed Handawi Saad Elmunafi, Noordin Mohd Yusof and Denni Kurniawan[4]: Empirical models for tool life, surface roughness, and cutting forces were developed within the range of cut- ting parameters selected. A combination of low cutting speed and feed was found to be the optimum cutting parameters to achieve long tool life, low surface rough- ness, and low cutting forces. So in this research paper AISI 420 work piece material and TiAlN-coated carbide insert selected.

Hrelja Marko, Klancnik Simon [5]: Due to the dynamic processes and increase of the machining parameters optimizing the information which is essential for production got significantly harder. The code could get adopted for broader spectrum of parameter optimization which means we could eliminate the factor of material in order to gain an optimization algorithm capable of optimizing parameters for different materials.

III. Research Methodology

The work-piece material used in this study is high chrome steel alloy by of ss420 similar to in high chrome steel its chemical composition is listed in Table 1. The hardness of this work-piece tested at a load of 56 HRC the range of 54-56 HRC.an average hardness of 56HRC.Turning was conducted with a Nitride ceramic insert (SNMG120408) supplied by Sandvik coromat. The rake angle of the insert was 90◦and the entry angle was 90◦.The research work in Ace Designer Jobber XL CNC machine and Fanuc CNC controller in ABC industry. For the high chrome steel for pree dimension work piece material in show table 4 result are mach. so selected machine and input parameter cutting speed, feed and depth of cut and response parameter is material removal rate. The Design of Experiments is considered as one of the most comprehensive approach in product/process developments so design of experiment with Taguchi method use So Taguchi method in three levels and three level use and mathematical mode developed in regression analysis.

Sr No	Carbon	Silicon	Manganese	Phosphorus	Sulphur	Chromium
1	0.530	0.330	0.400	0.033	0.031	12.070
Stan Value	0.16 min	1.00 max	1.00 max	0.040 max	0.035 max	12-14

Table 1:

IV. EXPERIMENTAL PROCEDURE

A. *The Taguchi Method and Design Of Experiments*

In this study, cutting speed, feed rates and depth of cut were investigated to determine the effect of machining parameters on the material removal rate. The Taguchi method experimental cutting parameters with three factors and three levels involve 9 experimental results. Therefore, Taguchi proposed a unique design of orthogonal array to investigate the full parameter with a small number of experimental trials in order to reduce the experimental process. This method make less the number of experiments by using orthogonal arrays and minimizes the effects of factors that cannot be controlled. The Taguchi's quality loss function approach was performed to calculate the deviation between the experimental values and the optimal cutting values. This function are further regenerated into a signal-to-noise (S/N) ratio and the cutting parameters are evaluated based on the S/N. The S/N ratio indications can be separated into three groups: the smaller-the-better, the larger-the-better, and the nominal –the -best. Hence, a larger-the-better has been debated to compute the S/N ratio.

Sr. no	Parameter	Value
1	Cutting speed (m/min)	215, 180, 145
2	Feed (mm/rev)	0.35, 0.31, 0.27
3	Depth of cut (mm)	4.0, 3.5, 3.0

Table 2: Cutting parameters used in the experiments

Feed rate, depth of cut and cutting speed were determined as the control factors with three levels each and workpiece materials high chrome steel. As previously mentioned, a Taguchi L9 orthogonal array design has been used and is shown in table 3.

Sr. no	Cutting speed (m/min)	Feed (mm/rev)	Depth of cut (mm)
1	215	0.35	4.0
2	215	0.31	3.5
3	215	0.27	3.0
4	180	0.35	3.5
5	180	0.31	3.0
6	180	0.27	4.0
7	145	0.35	3.0
8	145	0.31	4.0
9	145	0.27	3.5

Table 3: DOE L9 Table for Material removal rate

V. EXPERIMENTAL READING

In the L9 orthogonal array the experiment is conduct on the 9 level and 3 variables. Base on this level we find out the material removal rate and surface roughness for 'S' type (Nitride ceramic insert)

In the optimization of material removal rate the Taguchi L9 orthogonal array. The material removal rate optimization by the maximum value of material removal rate at specific speed, feed, depth of cut.

No	Cutting Speed (m/min)	Feed rate(mm/rev)	Depth of cut (mm)	Material removal rate (mm/mm3)
1	215	0.35	4.0	300976.1
2	215	0.31	3.5	233299.0
3	215	0.27	3.0	174608.2
4	180	0.35	3.5	220632.5
5	180	0.31	3.0	167512.6
6	180	0.27	4.0	194573.9
7	145	0.35	3.0	152604.3
8	145	0.31	4.0	179757.7
9	145	0.27	3.5	137483.0

Table 4: L9 Orthogonal array for Material removal rate of 'S' type Nitride ceramic insert

Sr no	Cutting Speed(m/min)	Feed rate (mm/rev)	Depth of cut (mm)	Material Removal rate (mm^3/min)
1	**215**	**0.35**	**4.0**	**300976.1**

Table 5: Optimization of material removal rate for 'S' type Nitride ceramic insert

VI. ANALYSIS AND DISCUSSION OF RESULTS

The effect on process parameters cutting speed, feed rate and depth of cut on material removal rate discussed in this section. The mean and S/N ratio of the quality characteristics for each variable at different levels were calculated from experimental data. The analysis of variance (ANOVA) of raw data and S/N ratio data is carried out to find the significant variables and to quantify their effects on the response characteristics. The most significant values of process parameters in terms of mean response characteristics are established by analysing the response curves and the ANOVA tables.

A. *Main Effect Plot For Means And S/N Ratio For Material Removal Rate of 'S' Type Nitride Ceramic Insert*

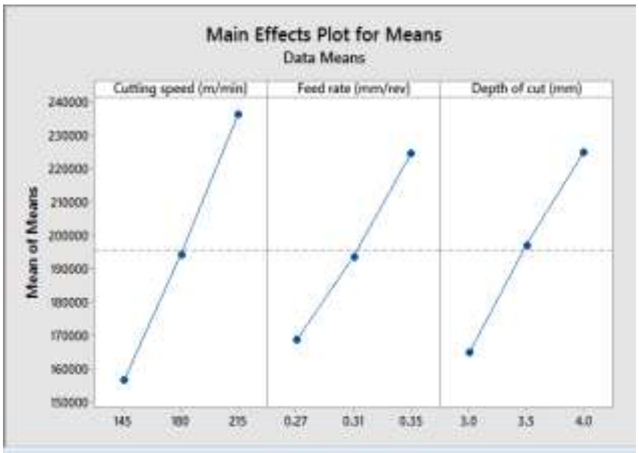

Fig. 1: Main effect plot for means for material removal rate of 'S' type Nitride ceramic insert

Fig 1 shows that the material removal rate is increase with the cutting speed then depth of cut and negligible effect on the feed rate. In this figure the cutting speed increase the material removal rate is increase with respect to depth of cut and feed rat gives the negligible effect on the material removal rate.

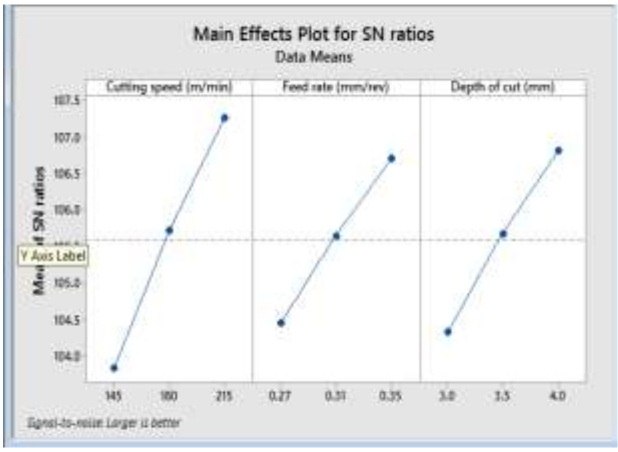

Fig. 2: Main effect plot for SN ratio for material removal rate of 'S' type Nitride ceramic type insert

Fig. 2 shows that the main effect plot for S/N ratio for material removal rate for 'S' type nitride ceramic insert. In this plot the material removal rate is increase with the with cutting speed respect to the depth of cut and feed.

B. Means and S/N Ratio for Material Removal Rate 'S' Type Nitride Ceramic Insert (Larger Is Better)

Sr no	Level	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of Cut (mm)
1	1	156615	168888	164908
2	2	194240	193523	197138
3	3	236294	224738	225103
4	Delta	79679	55849	60194
5	Rank	1	3	2

Table 6: Response Table for Means for Material removal rate 'S' type Nitride ceramic insert

Table 6 shows that the main affecting parameter for material removal rate for 'S' type Nitride ceramic inserts. In this table the main affecting parameter is cutting speed and depth of cut is the second affecting factor and feed rate is the third affecting factor for the material removal rate for 'S' type Nitride ceramic insert.

Sr no	Level	Cutting speed (m/min)	Feed rate (mm/rev)	Depth of Cut (mm)
1	1	103.8	104.5	104.3
2	2	105.7	105.6	105.7
3	3	107.3	106.7	106.8
4	Delta	3.4	2.2	2.5
5	Rank	1	3	2

Table 7: Response Table for S/N Ratio for Material removal rate 'S' type Nitride ceramic insert (Larger is better)

VII. REGRESSION ANALYSIS

Regression analysis of Material removal rate of 'S' type (Nitride ceramic) inserts respectively and also we found that the p value and F value of 'S' type insert statistically software.

Sr. no	**Source**	**DF**	**Adj SS**	**Adj MS**	**F-Value**	**P-Value**
1	Regression	3	19636941596	6545647199	146.96	0.000
2	Cutting speed (m/min)	1	9523218144	9523218144	213.81	**0.000**
3	Feed rate (mm/rev)	1	4678710881	4678710881	105.04	**0.000**
4	Depth of cut (mm)	1	5435012570	5435012570	122.02	**0.000**
5	Error	5	222704606	44540921		
6	Total	8	19859646202			

Table 8: Analysis of variance regression analysis for material removal rate for 'S' type nitride ceramic insert

Table 8 shows that the main affecting factor is all factors. The model is acceptable.

A. Model Summary

Sr no	S	R-sq	R-sq(adj)	R-sq(pred)
1	6673.90	**98.88%**	98.21%	95.39%

Table 9: Model summary for Material removal rate (mm3/min) 'S' type Nitride ceramic insert

Table 9 shows that the model summary of material removal rate of 'S' type Nitride ceramic inserts. In this model the R-sq **98.88%** value is so the model is acceptable.

B. Regression Equation

Material Removal Rate = -436269 + 1138.3 Vc + 698116 Fd + 60194 Ap

Where**,** Vc = Cutting Speed (m/min)

Fd = Feed (mm/rev)

Ap = Depth of Cut (mm)

VIII. RESULT AND DISCUSSION

The optimum result for output material removal rate in terms of machining parameter of cutting speed, feed rate and depth of cut for material high chrome steel in on CNC turning machine have been obtained. Base on the experimental result the 'S' type nitride ceramic insert gives the highest material removal rate. In the 'S' type nitride ceramic cutting parameter of cutting speed [215, 180 and 145 m/min], feed rate is [0.35, 031 and 0.27 mm/rev] and depth of cut is [4.0, 3.5 and 3.0mm] and the nose radius is constant 0.8. now apply this cutting parameter the optimum value of nitride ceramic insert the material removal rate is **300976.1** mm3/min at cutting speed is 215 m/min, feed rate is 0.35 mm/rev, depth of cut 4 mm.

IX. CONCLUSIONS

On use of insert shape 'S' type shape cutting insert gives value of MRR. Hence the MRR aspects the best suitable insert selected is 'S' type cutting insert. The better results have been obtained in terms of DOE techniques such as using statically software. 'S' type insert gives the higher material removal rate. Material removal rate for Taguchi analysis in most effective significant process parameter in cutting speed and depth of cut Mathematical model for material removal rate has been jonrliesed by regression analysis.

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