Analysis of Surface Roughness And Tool Wear of Ceramic Inserts In Face Milling of EN8 Material on Vertical Machining Centre

Pramod Prabhu Chavhan[1], Asso. Prof. V.S. Jadhav [2]
[1, 2] Dept of Mechanical
[1, 2] Government college of Engineering, Karad. Shivaji University, Maharashtra, India

Abstract- *VMC's performance is largely affected by their thermal behaviour as well as stiffness. This experiment establishes a mechanical model for VMC by using the FEA to study thermal expansion & mechanical deformation. To improve the efficiency this model takes into account contact stiffness & thermal contact resistance of joints. Experiment carries a parametric study using work table feed, tool rotation speed. Ceramic was insert materials used to carry out the study of surface roughness (Ra) & Tool wear (Tw). The experimental data was converted to signal to noise ratio as per Taguchi method. To check the feasibility of the experiment results ANOVA(analysis of variance) was performed using statistical software, MINITAB 17.*

Keywords- Surface roughness, Tool wear, Taguchi technique, Signal to Noise ratio, Ceramic Insert

I. INTRODUCTION

A. Overview and Problem statement

VMC is a type of CNC. Manufacturing of components like bulkheads, gear boxes, frames etc. requires several operations to be done like milling, boring, drilling etc. With CNC, operations of milling, drilling & lathe can be done in single machine tool with lot of time saving. CNCs use ATC(Automatic tool changer), APC(automatic pallet changer), CNC servo system, feedback system etc. to complete main aim of reduction of production time. VMC's performance is largely affected by their thermal behavior & stiffness. So It becomes important to study the thermal expansion & mechanical deformation by studying contact stiffness & thermal contact resistance of joints & use obtained knowledge to improve the efficiency of VMC operations.

B. Proposed work

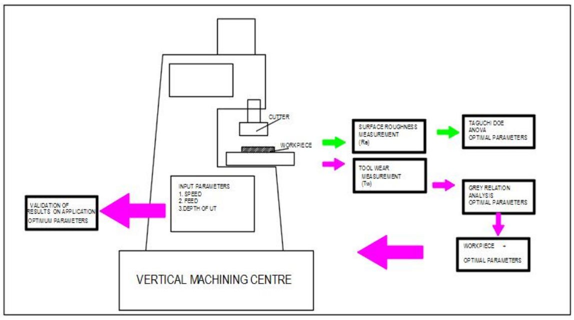
M/s. Amar Technocraft, Ahmednagar does machining of gear box casings and different workpieces on vertical machining center. Objective of present work is to analyze tool wear in Vertical Machining Center.
Therefore following work will be carried out.

1. Design of experimental set up for tool wear of Vertical Machining Center.
2. Parametric study using work table feed, tool rotation speed.

II. EXPERIMENTAL WORK

A. Setup

Machine Name: "Supermax YCM-105A VMC "
Feed Range:1 mm/min to 10,000 mm/min.
Spindle Speed Range:10 to 6,000 rpm
Work-Table Size: 650 mm × 450 mm × 600 mm (L×B×H)



B. Design of experiment

The design of experiment technique is tool, which permits us to carry out the modelling analysis of influence of process variables on the response variables. In turning operation, the depth of cut(mm), spindle speed, feed rate of cutting tool are main parameters. DoE helps to pin point the sensitive parts & sensitive areas in design that cause problems in Yield. Minitab 17 software is used for DoE. DoE technique, Orthogonal Arrays(OAs) is employed in Taguchi method to systematically vary & test the different levels of each control factors. Commonly used OAs includes the L4, L9, L12, L16, L18 & L27. We are using L16 here. Designed experiments are often carried out in four phases: planning, screening (also called process characterization), optimization, and verification.

C. Performing Taguchi designed experimental steps:

1. Choose control factors for inner array &noise factors for outer array
2. Use Create Taguchi Design to generate Taguchi design(OA)
3. Use Modify Design to rename the factors, change factor levels etc.
4. Use Display Design to change the units in which Minitab expresses the factors in the worksheet
5. Perform exp. & collect response data. Then enter data in Minitab worksheet
6. Use Analyse Taguchi Design to analyse experimental data
7. Use Predict Results to predict S/N ratios & response characteristics for selected new factor settings.

III. RESULTS & DISCUSSION

A. Selection of process parameters

Based on the experimental results discussed in chapter 4 , important parameters have been selected to analyse their effect on various machining parameters using Taguchi's design of experiment technique. In present work, three input parameters namely speed, feed, depth of cut, have been investigated during turning of oil hardened non shrinkage steel (50 to 55 HRc). The machining parameters as are as displayed in table below:

Table 6.1a: Process variables and their levels

Parameter	Level-1	Level-2	Level-3	Level-4
SPEED	1200	1000	800	600
FEED	0.2	0.18	0.16	0.14
DOC	1.5	1.2	0.9	0.6

B. Selection of orthogonal array and parameter assignment: The orthogonal array forms the basis for the experimental analysis in Taguchi method. The selection of orthogonal array is concerned with the total degree of freedom of process parameters.. The degree of freedom for the orthogonal array should be greater than or at least equal to that of the process parameters. Thereby, a L16 orthogonal array having degrees of freedom equal to 15 is considered in present case. The experimental layout is shown in Table 6.2.

Table 6.2a: Orthogonal array for L16

Exp. No.	A	B	C	D
1.	1	1	1	1
2.	1	2	2	2
3.	1	3	3	3
4.	1	4	4	4
5.	2	1	2	3
6.	2	2	1	4
7.	2	3	4	1
8.	2	4	3	2
9.	3	1	3	4
10.	3	2	4	3
11.	3	3	1	2
12.	3	4	2	1
13.	4	1	4	2
14.	4	2	3	1
15.	4	3	2	4
16.	4	4	1	3

C. Experimental results for ceramic insert
Based on the experimental layout depicted in Table 7.2, the experiments were performed in random order Two machining characteristics namely surface roughness (Ra), and tool wear (Tw) were measured. Ra has been expressed as a value which was observed from machine tool monitor screen. SR value (in µm) was measured in terms of mean absolute deviation (Ra) using the digital surface tester Mitutoyo Portable Surface Roughness Tester Surftest SJ-210.The tool wear was measured using high magnification (200x) high resolution microscope image capture device and the tool wear is expressed in terms of value using Cooling Tech measurement software. . Table 5.3 depicts the observed results.

Table 6.3a: Results of experiment with CERAMIC Insert

Speed	Feed	DoC	Ra_W	Rt_W	Rz_W	Tw_W
1200	0.2	1.5	0.457938	3.984058	3.297151	0.093809
1200	0.18	1.2	0.434235	3.777844	3.126491	0.088872
1200	0.16	0.9	0.316669	2.755021	2.280018	0.07406
1200	0.14	0.6	0.29107	2.53231	2.095705	0.069123
1000	0.2	1.2	0.438975	3.819086	3.160623	0.078997
1000	0.18	1.5	0.387777	3.373664	2.791998	0.083935
1000	0.16	0.6	0.379244	3.299427	2.73056	0.069123
1000	0.14	0.9	0.369763	3.216941	2.662296	0.078997
800	0.2	0.9	0.402947	3.505641	2.90122	0.07406
800	0.18	0.6	0.393466	3.423155	2.832956	0.07406
800	0.16	1.5	0.434235	3.777844	3.126491	0.088872
800	0.14	1.2	0.375452	3.266432	2.703254	0.07406
600	0.2	0.6	0.449405	3.909821	3.235714	0.07406
600	0.18	0.9	0.440872	3.835584	3.174276	0.07406
600	0.16	1.2	0.432339	3.761346	3.112838	0.078997
600	0.14	1.5	0.42665	3.711855	3.07188	0.078997

IV. RESULT ANALYSIS AND DISCUSSION:

The turning experiments were conducted by using the parametric approach of Taguchi's method. Using Taguchi approach, only main effect of individual parameters have been evaluated. The effects of individual turningprocess parameters, on the machining characteristics namely surface roughness (Ra) and Tool Wear (Tw) have been discussed in this section. Experimental data have been converted into signal to noise (S/N) ratio as suggested by Taguchi method. Ra and Tw characteristics are analysed using "lower the better" type. In order to evaluate the feasibility and sufficiency of the present experimental results, analysis of variance (ANOVA) has been performed by using, a statistical software, MINITAB 17. Using ANOVA, the percentage contribution of various process parameters can be estimated. Thus, information about how significant the effect of each process parameter on performance characteristics of interest can be obtained.

Taguchi Analysis: RA_C versus SPEED, FEED, DOC

Table :6.4a Response Table for of means of Ra

Level	SPEED	FEED	DOC
1	0.4373	0.3657	0.3783
2	0.4015	0.3906	0.3826
3	0.3939	0.4141	0.4203
4	0.3750	0.4373	0.4267
Delta	0.0623	0.0716	0.0484
Rank	2	1	3

Table :6.5 aResponse Table S/N ratios of Ra

Level	SPEED	FEED	DOC
1	7.186	8.817	8.548
2	7.938	8.235	8.410
3	8.111	7.672	7.547
4	8.684	7.194	7.414
Delta	1.499	1.623	1.134
Rank	2	1	3

Effect of surface parameters on Surface Roughness(Ra):

In order to see the effect of process parameters on Surface Roughness (Ra), experiments were performed as per L16 orthogonal array and then raw data have been converted into S/N ratio . Before optimizing the parameters, adequacy of the results have been analysed by residual plots. Residual plots are used to evaluate the data for the problems like non normality, non-random variation, non-constant variance, higher-order relationships, and outliers (Kanlayasiri and Boonmung, 2007; Kanagarajan et al., 2008).

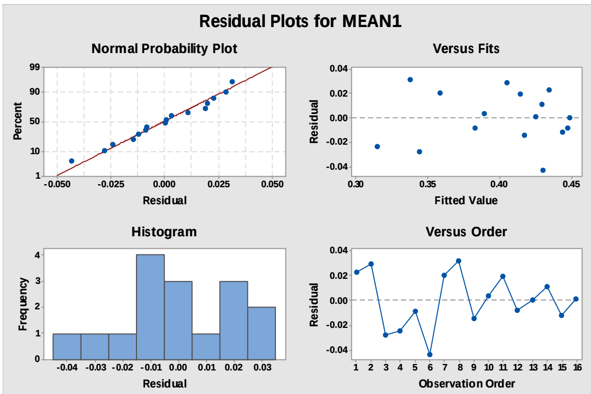


FIG :6.1a Residual plots for mean Ra

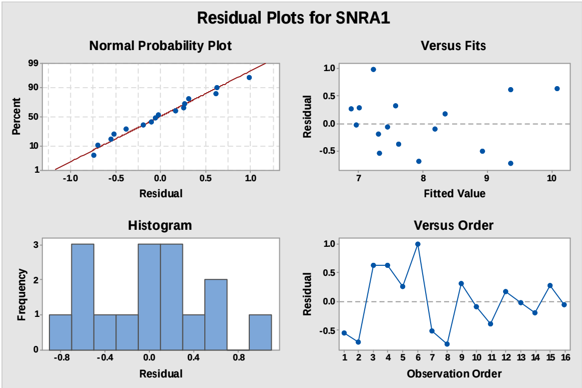


FIG : 6.2a Residual plots for S/N ratios of Ra

It can be seen from Figure 5.3 and 5.4 that the residuals follow an approximately straight line in normal probability plot and approximate symmetric nature of histogram indicates that the residuals are normally distributed. Residuals possess constant variance as they are scattered randomly around zero in residuals versus the fitted values. Since residuals exhibit no clear pattern, there is no error due to time or data collection order.

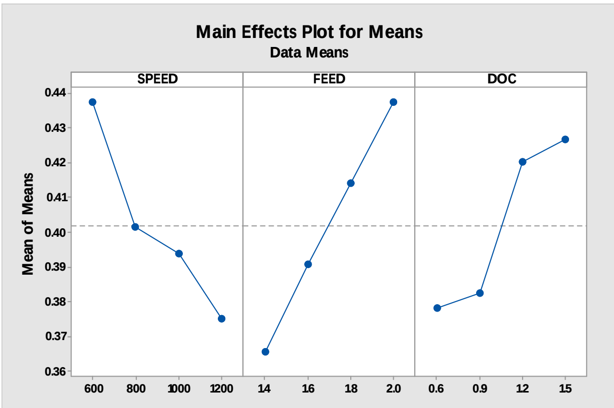


FIG .6.3: aResponse Main effects plot of Means of Ra

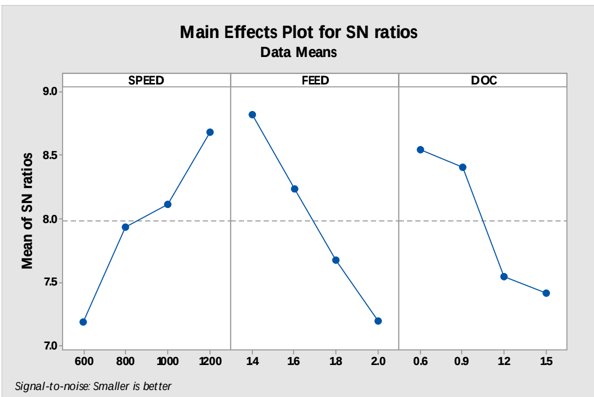


FIG : 5.4a Response Main effects plot of SN ratios of Ra

It is clear from the responses above that the Surface finish improves with increase in speed indicated by the trend in graph whereas the increase in feed results in poor surface finish, the change in DOC gives an ambiguous result.

ANALYSIS OF VARIANCE:

ANOVA OF MEAN

Analysis of Variance

TABLE : 5.6 aAnova of Means of Ra

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SPEED	3	0.008170	0.002723	2.35	0.171
FEED	3	0.011352	0.003784	3.27	0.101
DOC	3	0.007521	0.002507	2.17	0.193
Error	6	0.006941	0.001157		
Total	15	0.03398			

ANOVA OF S/N RATIOS

Analysis of Variance

TABLE : 5.7 a Anova of S/N ratios of Ra

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SPEED	3	4.583	1.5276	2.40	0.167
FEED	3	5.911	1.9703	3.09	0.111
DOC	3	4.057	1.3524	2.12	0.199
Error	6	3.821	0.6369		

Selection of optimum level of parameters:

The least variation and the optimal design are obtained by means of the S/N ratio. Higher the S/N ratio, more stable the achievable quality (Tosun et al., 2004). Figure 7.4 shows the S/N ratio plots for MRR. It is clear from Figure 5.4, highest S/N ratio first level of SPEED (1200), level-4 of FEED (0.14 mm/rev), level-4 of DOC (0.6 mm Therefore, the optimal setting of process parameters which yield maximum surface finish is $A_1B_4C_4$

ANALYSIS OF TOOL WEAR

Taguchi Analysis: Tw_C versus SPEED, FEED, DOC

Table 6.4b: Response Table of means of Tw

Level	SPEED	FEED	DOC
1	0.07653	0.07529	0.07159
2	0.07776	0.07776	0.07529
3	0.07776	0.08023	0.08023
4	0.08147	0.08023	0.08640
Delta	0.00494	0.00494	0.01481
Rank	3	2	1

Response Table for Signal to Noise Ratios Smaller is better

Table6.5b: Response Table for S/N ratios of Tw

Level	SPEED	FEED	DOC
1	22.33	22.48	22.91
2	22.21	22.22	22.47
3	22.21	21.94	21.93
4	21.85	21.95	21.29
Delta	0.48	0.54	1.62
Rank	3	2	1

Effects of process parameters on Tool Wear(Tw):

In order to see the effect of process parameters on Tool Wear (Tw), experiments were performed as per L16 orthogonal array and then raw data have been converted into S/N ratio . Before optimizing the parameters, adequacy of the results have been analysed by residual plots. Residual plots are used to evaluate the data for the problems like non normality, non-random variation, non-constant variance, higher-order relationships, and outliers (Kanlayasiri and Boonmung, 2007; Kanagarajan et al., 2008).

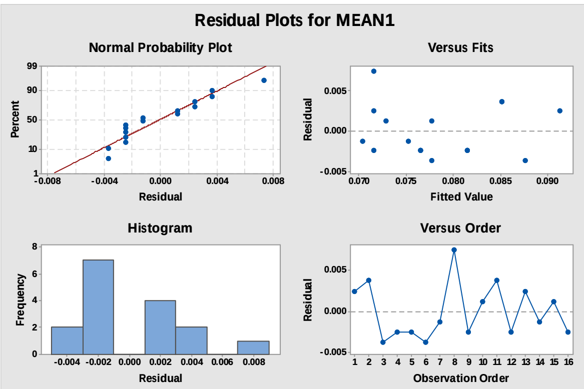


FIG : 6.1b Residual plots for mean (Tw)

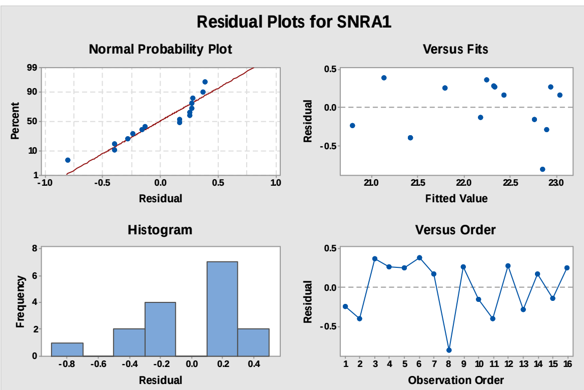


FIG : 6.2b Residual plots for S/N ratios of (Tw)

It can be seen from Figure 5.3 and 5.4 that the residuals follow an approximately straight line in normal probability plot and approximate symmetric nature of histogram indicates that the residuals are normally distributed. Residuals possess constant variance as they are scattered randomly around zero in residuals versus the fitted values. Since residuals exhibit no clear pattern, there is no error due to time or data collection order.

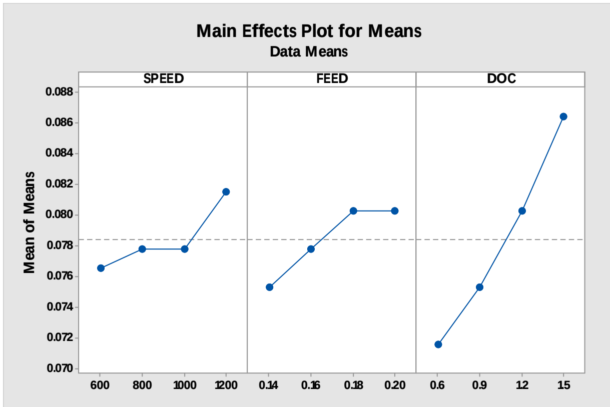


FIG : 6.3b Response Main effects plot of Means of Tw

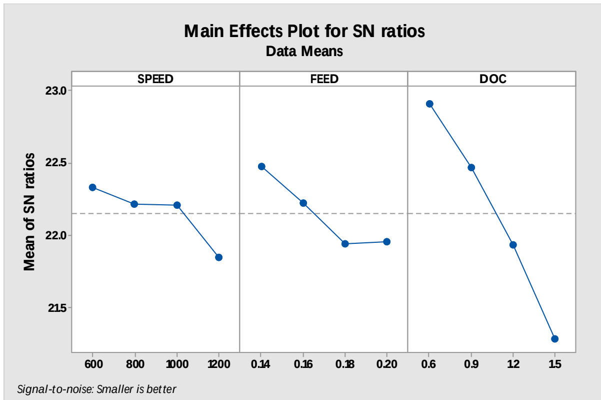


FIG : 6.4b Response Main effects plot of SN ratios of (Tw)

It is clear from the responses above that the Surface finish improves with increase in speed indicated by the trend in graph whereas the increase in feed results in poor surface finish , the change in DOC gives an ambiguous result.

ANALYSIS OF VARIANCE:

ANOVA OF MEAN

Analysis of Variance

TABLE 5.6b: Anova of Means of (Tw)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SPEED	3	0.000055	0.000018	0.69	0.589
FEED	3	0.000067	0.000022	0.85	0.517
DOC	3	0.000494	0.000165	6.23	0.028
Error	6	0.000158	0.000026		
Total	15	0.000774			

ANOVA OF S/N RATIOS

Analysis of Variance

TABLE : 6.7b Anova of S/N ratios of (Tw)

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SPEED	3	0.5175	0.1725	0.56	0.660
FEED	3	0.7784	0.2595	0.84	0.518
DOC	3	5.8705	1.9568	6.37	0.027
Error	6	1.8443	0.3074		
Total	15	9.0107			

Selection of Optimum level of Parameters:

The least variation and the optimal design are obtained by means of the S/N ratio. Higher the S/N ratio, more stable the achievable quality (Tosun et al., 2004). Figure6.4 shows the S/N ratio plots for MRR. It is clear from Figure 6.4, highest S/N ratio level-4 of SPEED (600), level-4 of FEED (0.14 mm/rev), level 4 of DOC (1.2mm Therefore, the optimal setting of process parameters which yield maximum surface finish $\mathbf{A_4B_4C_4}$

V. CONCLUSIONS FOR CERAMIC INSERTS

1. Using Taguchi's method, four machining characteristics namely material Surface roughness (Ra), Tool Wear (Tw) have been optimized individually.
2. In case of Surface finish (Ra), the optimal setting of process parameters has been found at $\mathbf{A_1B_4C_3}$. Thus the optimized value of Surface finish with conventional inserts using the optimal parameters is 0.5 µRa
3. In case of Tool Wear, the optimal setting of process parameters has been found at $\mathbf{A_4B_4C_4}$. Thus the optimized value of Tool Wear with conventional inserts using the optimal parameters is 0.08 mm

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