Experimental Investigation on Surface Roughness in Turning of EN8K steel using PTFE / Nylon66 Liners for Carbide Insert Cutting Tools

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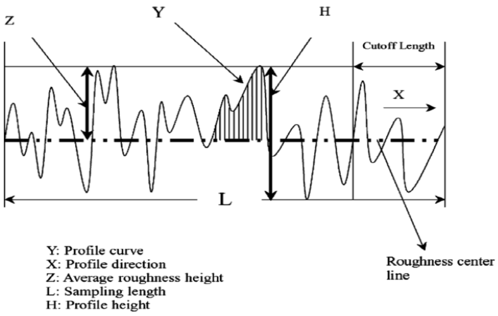
ABSTRACT

Optimization of Multi response is now-a-days mostly used optimization technique which is better than single response optimizing technique because all the output is affected at a time by all the input factors .The objective of this project work is to investigate on Surface Roughness in Turning of EN8K steel using PTFE / Nylon66 Liners for Carbide Insert Cutting Tools determine the optimal setting of cutting parameters (speed(N)m/min , depth of cut(d) mm , feed(f)mm/rev) of the tool to have a reduced tool vibration (in terms of peak acceleration) and surface roughness(Ra). In this work the experiment has been carried out in lathe dry turning (without using cutting fluid) of a commercially available EN8K Steel as a work material and carbide insert tool. The ranges of process cutting parameters are speed (750,500,350,275rpm), feed rate (0.2,018,0.16,0.14mm/rev), depth of cut (1.5,1.2,0.9,0.6mm). For this experiment Taguchi design of experiment was carried out for PTFE and Nylon liner to collect the data for surface roughness and tool vibration by employing Taguchi orthogonal array to conduct experiments in an organized manner. Analysis of variance (ANOVA) is performed to optimize the multi response parameters on turning operation. The result indicates that Surface finish is observed to improve with application of Nylon liner and the results are conformed by a confirmatory test.

Keywords: Surface Roughness, EN8K, PTFE, Nylon, Design of Experiment, Taguchi, ANOVA etc

I. INTRODUCTION

The challenge of modern machining industries is mainly focused on the achievements of high quality in terms of work piece dimensional accuracy ,surface finish, high production rate, less wear on the cutting tool, economy of machining in terms of cost saving and increase the performance of the product with reduced environmental impact[1]. Surface roughness plays an important role in many areas and is factor of great importance in evaluation of machining accuracy [2]. Turning is the process whereby a single point cutting tool removes unwanted material from the cylindrical work piece and the tool is fed parallel to the axis of rotation. It can be done manually, in a traditional form of lathe, which frequently requires continuous supervision by the operator, or by using a computer controlled and automated lathe which does not. In turning operation vibration is a frequent problem .Vibration in machine tool is directly affecting the surface finish of the work material in turning process. So vibration of a machine tool is one of the major factors limiting its performance. The vibration occurring in the machine tool is due to the dynamic nature of force acting during the turning operation on the cutting tool [3]. Vibration can be measured in terms of peak acceleration, r.m.s value of velocity, peak to peak displacement.



The average surface roughness is given by [5]

Ra = $\frac{1}{L}\int_0^L |y(x)|dx$, ………… (1)

Where Ra is the arithmetic average deviation from mean line, L is the sampling length and Y the coordinate of the profile curve.

Machining vibration accompanies every cutting process. Being influenced by many sources, such as machine structure, tool type, work material, etc., the composition of the machining vibration is complex. However, at least two types of vibrations, forced vibration and self-excited vibration, were identified as machining vibrations [1], [2].

In turning operation, tool vibration is a common problem and it affects the performance of a machine, tool life and surface finish of the work material. The standard procedure adopted to avoid vibration during machining is by careful planning of the cutting parameters and damping of cutting tool. There have been many investigations on vibration prediction and control in turning.

II.RELEVANCE OF PROJECT

Reliable vibration reduction method is one of the important aspects for achieving a good dimensional accuracy and surface finish during turning operation in an manufacturing system. The surface quality is influenced by cutting speed, feed rate and depth of cut and many other parameters. Speed, feed and depth of cut are used as input parameters and dimensional accuracy, surface finish are used as measured output parameters. The Vibration parameters like displacement (δ), velocity (Ve), acceleration (a) are other measured parameters measured using a Vibrometer. In the present study attempt has been made to investigate the effect of Turning of

EN8K steel on surface roughness and Vibration Parameters through generating experimental data by performing turning test on EN8k steel material using PTFE / Nylon 66 Liners for Carbide Insert Cutting Tools by variation of suitable machining parameters namely Speed, feed and depth of cut.

III. NEED OF OPTIMIZATION THE PROCESS

It is much more important to limit vibrations of the machine tool structure because 1. vibrations in machine tool results in poor surface finish, cutting edge damage, and irritating noise. 2. It also set up frequent stress cycles with resonance to occur. 3. It also causes fatigue failure.

The present study thus aims at the vibration reduction of the tool by suitable altering the packing materials as liners below the tool Speed, feed, depth of cutting are used as input parameters and dimensional accuracy, surface finish are used as measured output parameters. The Vibration parameters like displacement (δ), velocity (Ve), acceleration are other measured parameters measured using a vibrometer The experimental data will be generated by performing turning test on EN8k material by variation of suitable machining parameters namely Speed, feed, depth of cut.

IV.PROBLEM STATEMENT

The dynamic motion between work piece and cutting tool during turning operation produce vibrations which result in unacceptable surface finish and dimensional errors. The present work is to investigate the passive vibration damping method of using PTFE and Nylon 66 packing liners for carbide insert cutting tool during turning operation.

V.PROJECT OBJECTIVE

The objective is to investigate the effect of Turning of EN8K steel using PTFE / Nylon 66 Liners for Carbide Insert Cutting Tools on surface roughness and Vibration Parameters.

The experimental data will be generated by performing turning tests on EN8k material by variation of suitable machining parameters namely Speed, feed, depth of cut and measurement of process output parameters and vibration parameters with PTFE and Nylon 66 respectively packing liners for Carbide Insert Cutting Tool.

VI.EXPERIMENTAL SETUP

Work Piece Material:

EN8K: Unalloyed medium carbon Steel (BS 970 080m40) has high strength levels compared to normal bright Mild Steel, due to thermo mechanical rolling. EN8K is suitable for all round engineering purposes that may require a Steel of greater strength.

Table No: 1 Experimental Condition

Work Piece Material	**EN8K Steel**
Length of the Work Piece	**100 mm**
Dia. of the Work Piece	**50 mm**

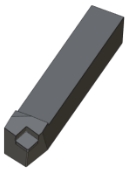
Table No: 2 Chemical Composition of EN8 Steel

Std	Grade		C	Mn	Si	P	S
BS 970	EN8/ 080M40	Min	0.35	0.60	0.05	0.015	0.015
		Max	0.45	1.00	0.35	0.06	0.6

Table No: 3 Physical Properties of EN 8 Steel

Maximum stress	**850 N/mm2**
Yield stress	**465 N/mm2**
Elongation	**16%**
Proof Stress(0.2%)	**450 N/mm2**
Density	**7.87gm/cm3**

Tool Holder:



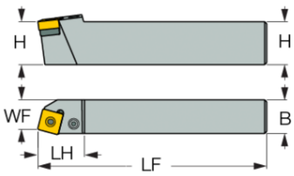
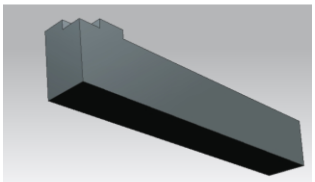


Fig.2. Tool Holder



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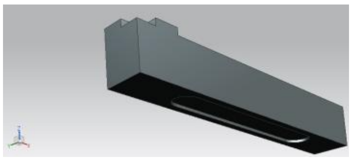

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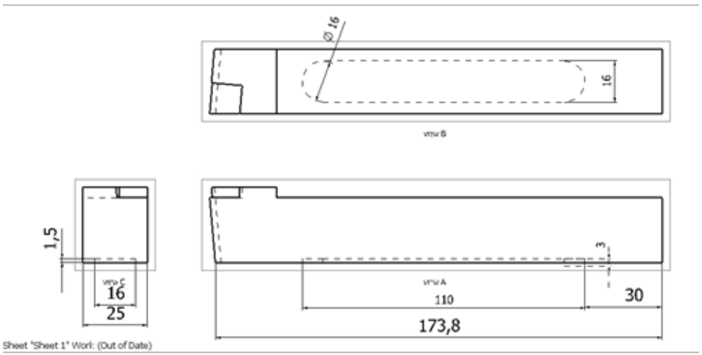
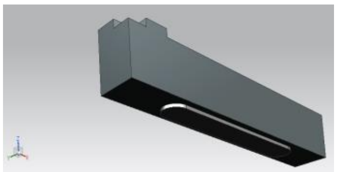


c.

Fig.3.a.b.c. Tool Holder without Recess & with Recess



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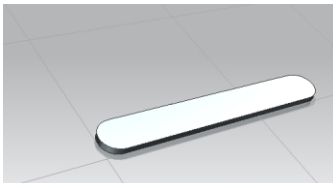
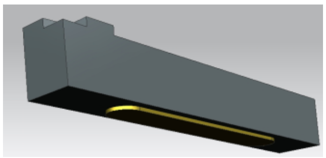


b.

Fig.4.a.b. Tool Holder with PTFE Liner fitted



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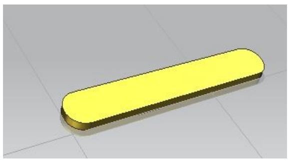

b.

Fig.5.a.b. Tool Holder with Nylon Liner fitted

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Machine Tool Used:

Fig-6 Centre Lathe

Testing Equipment:

a. Portable Roughness Tester Surftest SJ-210

b. Digital Tachometer

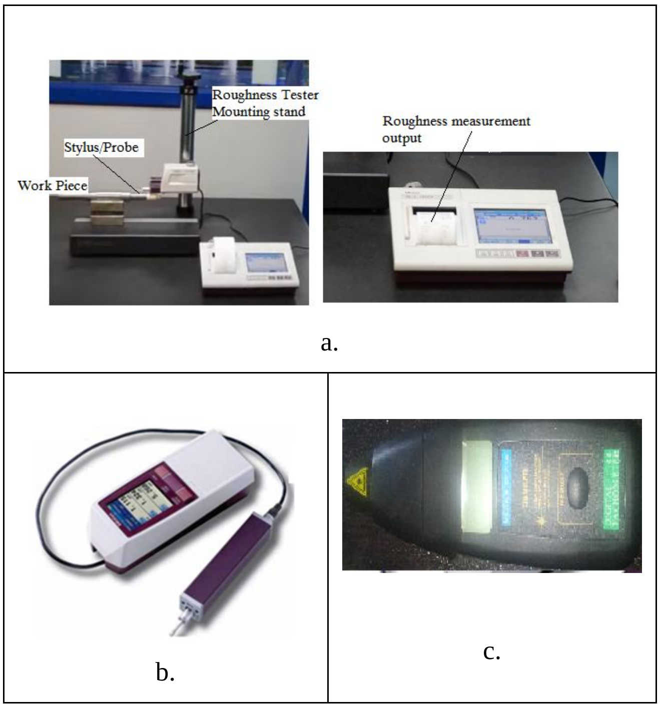

Fig.7 Equipment and instruments used during experiments

PLANNING OF EXPERIMENTS

Design of Experiments

To use the statistical approach in designing and analyzing an experiment, it is necessary to have a clear idea in advance of exactly what is to be studied, how the data are to be collected, and at least a qualitative understanding of how these data are to be analysed. [2]. The present experiments were designed on the basis of these guidelines. The step-by-step procedure which was used in designing these experiments is outlined below:

1. Define problem statement

The objective of the experiments is to determine the influence of various process parameters and their interactions on the response in using PTFE and Nylon 66 packing liners for carbide insert cutting tool during turning operation by developing mathematical models.

2. Selection of response variables

In selecting the response variables, it should be ensured that these variables provide useful information about the process performance under study. Following measures of performance (response variables) were chosen

- Surface Roughness (Ra)
- Dimensional Tolerance (Tw)

3. Selection of process variables

Trial experiments were conducted for selection of input parameter with carbide insert cutting tool with a tool holder on local work material. Based on the trial experiments conducted, the following process variables are selected for further experimentation.

Table 4 Process variables and their levels

Parameter	**Unit**	**Level-1**	**Level-2**	**Level-3**	**Level-4**
SPEED	**rpm**	**750**	**500**	**350**	**275**
FEED	**mm/rev**	**0.2**	**0.18**	**0.16**	**0.14**
DOC	**mm**	**1.5**	**1.2**	**0.9**	**0.6**

2) EXPERIMENTAL RESULTS OF PTFE

Table 5 Results of experiment with PTFE

Std. order	Speed rpm	Feed mm/rev	DoC mm	Ra µm	Rt µm	Rz µm
1	750	0.2	1.5	1.2825	11.15775	9.234
2	750	0.18	1.2	1.03645	9.017115	7.46244
3	750	0.16	0.9	0.83505	7.264935	6.01236
4	750	0.14	0.6	0.75335	6.554145	5.42412
5	500	0.2	1.2	1.19035	10.35605	8.57052
6	500	0.18	1.5	1.0849	9.43863	7.81128

7	500	0.16	0.6	1.05355	9.165885	7.58556
8	500	0.14	0.9	0.9234	8.03358	6.64848
9	350	0.2	0.9	1.33665	11.62886	9.62388
10	350	0.18	0.6	1.2274	10.67838	8.83728
11	350	0.16	1.5	1.254	10.9098	9.0288
12	350	0.14	1.2	0.76475	6.653325	5.5062
13	275	0.2	0.6	2.1736	18.91032	15.64992
14	275	0.18	0.9	1.13905	9.909735	8.20116
15	275	0.16	1.2	0.8417	7.32279	6.06024
16	275	0.14	1.5	1.026	8.9262	7.3872

VII.RESULT ANALYSIS AND DISCUSSIONS

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 turning process parameters, on the machining characteristics namely surface roughness (Ra) and Tolerance (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

Response Table for Signal to Noise Ratios

Smaller is better

Level	SPEED	FEED	DOC
1	-1.6501	1.3147	-1.6291
2	-0.9841	0.1609	-0.3483
3	-0.4955	-0.9823	0.5005
4	0.3884	-3.2346	-1.2645
Delta	2.0386	4.5494	2.1296
Rank	3	1	2

Table 6 Response Table for S/N ratios of Ra

Response Table for Means

Level	SPEED	FEED	DOC
1	1.2951	0.8669	1.3020

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2	1.1457	0.9961	1.0585
3	1.0631	1.1220	0.9583
4	0.9768	1.4958	1.1619
Delta	0.3182	0.6289	0.3437
Rank	3	1	2

Table 7 Response Table of means of Ra

Effect Of Process Parameters On Surface Roughness (Ra)

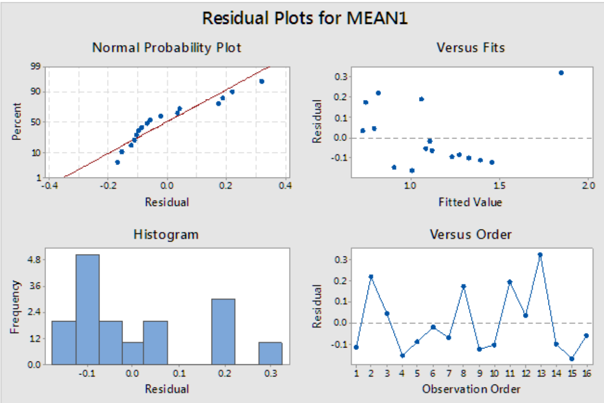

Fig 8 Residual plots for mean Ra

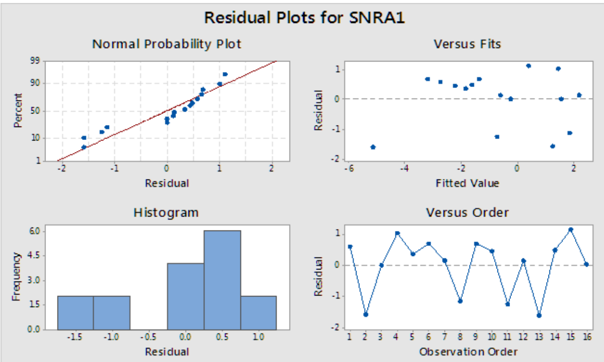

Fig 9 Residual plots for S/N ratios of Ra

It can be seen from Figure 8 and 9 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.

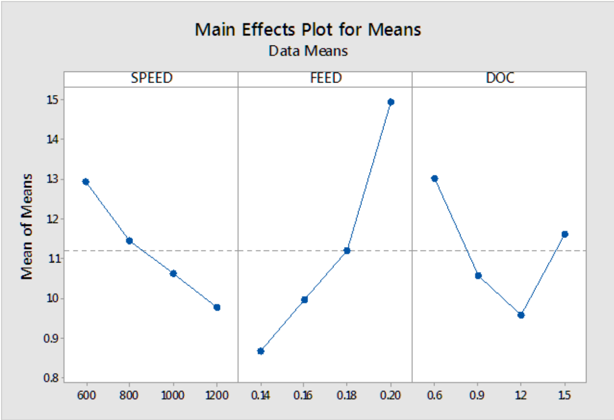

Fig 10 Response Main effects plot of Means of Ra

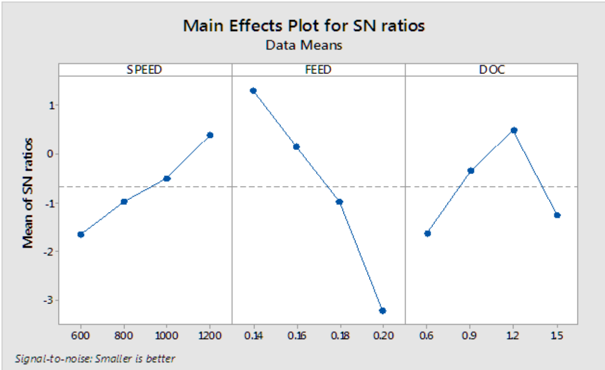

Fig 11 Response Main effects plot of SN ratios of Ra

It is clear from the responses above that the Surface finish improves with increase in speed indicated by the trend in graph where as 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

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SPEED	3	0.2202	0.07341	1.31	0.354
FEED	3	0.8826	0.29419	5.26	0.041
DOC	3	0.2591	0.08638	1.54	0.297
Error	6	0.3357	0.05595		
Total	15	1.6976			

Table 8 Anova Of Means Of Ra

ANOVA OF S/N RATIOS

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
SPEED	3	8.836	2.945	1.47	0.315
FEED	3	45.214	15.071	7.50	0.019
DOC	3	10.983	3.661	1.82	0.243
Error	6	12.055	2.009		
Total	15	77.089			

Table 9 Anova of S/N ratios of Ra

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 Ra. It is clear from Figure 11, highest S/N ratio first level of SPEED (750), THIRD level of FEED (0.14 mm/rev), third level of DOC (1.2mm Therefore, the optimal setting of process parameters which yield maximum surface finish is A_1B_4C

3) EXPERIMENTAL RESULTS FOR NYLON

Table 10 Results of experiment with Nylon

Std. order	Speed rpm	Feed mm/rev	DoC mm	Ra µm	Rt µm	Rz µm
1	750	0.2	1.5	0.457938	3.984058	3.297151
2	750	0.18	1.2	0.434235	3.777844	3.126491
3	750	0.16	0.9	0.316669	2.755021	2.280018
4	750	0.14	0.6	0.29107	2.53231	2.095705
5	500	0.2	1.2	0.438975	3.819086	3.160623
6	500	0.18	1.5	0.387777	3.373664	2.791998
7	500	0.16	0.6	0.379244	3.299427	2.73056
8	500	0.14	0.9	0.369763	3.216941	2.662296

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9	350	0.2	0.9	0.402947	3.505641	2.90122
10	350	0.18	0.6	0.393466	3.423155	2.832956
11	350	0.16	1.5	0.434235	3.777844	3.126491
12	350	0.14	1.2	0.375452	3.266432	2.703254
13	275	0.2	0.6	0.449405	3.909821	3.235714
14	275	0.18	0.9	0.440872	3.835584	3.174276
15	275	0.16	1.2	0.432339	3.761346	3.112838
16	275	0.14	1.5	0.42665	3.711855	3.07188

Result Analysis And Discussions

Taguchi Analysis: RA_C versus SPEED, FEED, DOC

Response Table for Means

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 11 Response Table for of means of Ra

Response Table for Signal to Noise Ratios

Smaller is better

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

Table 12 Response Table S/N ratios of Ra

Effect Of Process Parameters On Surface Roughness (Ra)

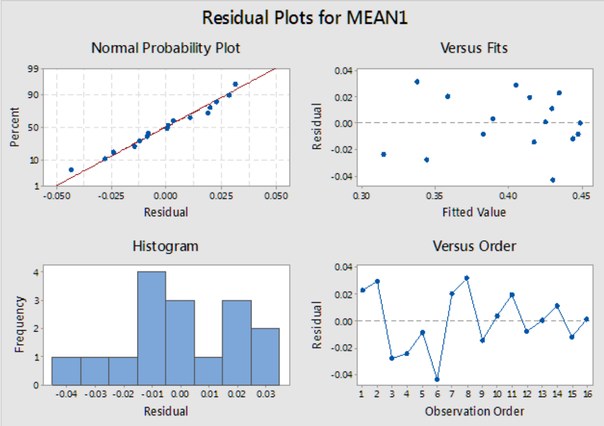

Fig 12 Residual plots for mean Ra

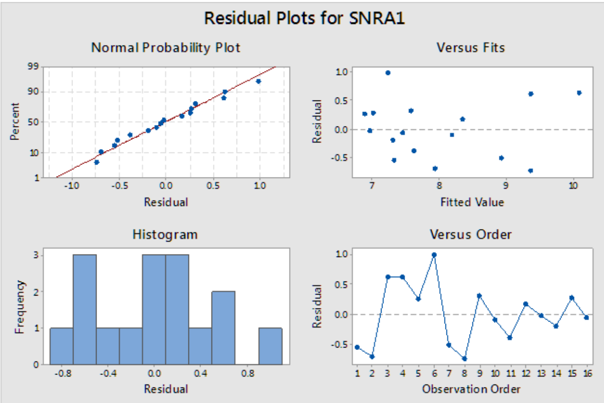

Fig 13 Residual plots for S/N ratios of Ra

It can be seen from Figure 12 and 13 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.

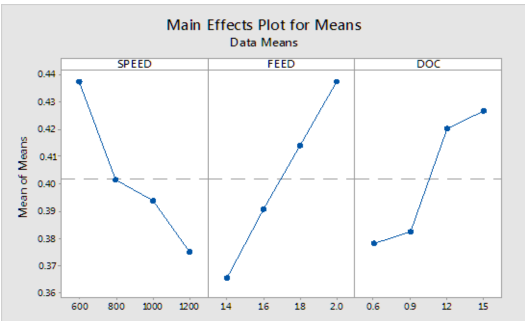

Fig 14 Response Main effects plot of Means of Ra

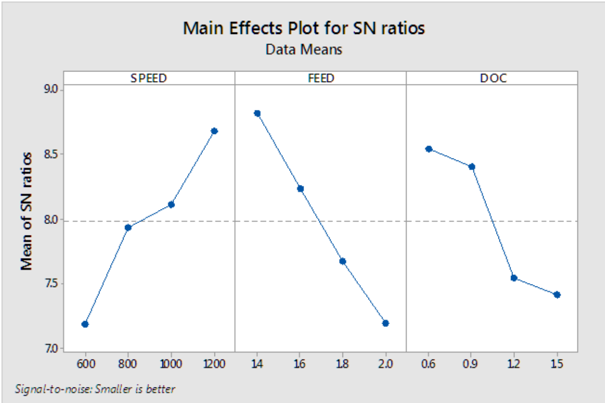

Fig 15 Response Main effects plot of SN ratios of Ra

It is clear from the responses above that the Surface finish improves with increase in speed indicated by the trend in graph where as 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

Source	DF	Adj SS	AdjMS	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			

Table 13 Anova of Means of Ra

ANOVA OF S/N RATIOS

Analysis of Variance

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		

Table 14 Anova of S/N ratios of Ra

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 Ra. It is clear from Figure 15, highest S/N ratio first level of SPEED (750), 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 $A_1B_4C_4$

VIII.CONCLUSIONS

1. Design of Experiment using Taguchi method was done to optimize the parameters for best surface finish
2. The Surface finish is observed to improve with application of Nylon liner.
3. The optimal level of parameters are as follows for PTFE to obtain optimal surface finish Speed (750), Feed (0.14 mm/rev), DOC (1.2mm) for MQL plain
4. The optimal level of parameters are as follows for Nylon SPEED (750), THIRD level of FEED (0.14 mm/rev), third level of DOC (1.2mm for MQL -Additive
5. The Nylon shows better overall results and it is recommended for use.
6. Speed of 750 rpm and 500 rpm are found to be effective and optimal for best results of Surface finish.

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