



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

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## ABSTRACT

Reliable vibration reduction method is one of the important aspects for achieving a good dimensional accuracy and surface finish during turning operation in a manufacturing system. An effort is being made to minimize vibration in order to improve surface finish and dimensional tolerance in lathe dry turning process by passive damping technique. In the present work, prediction is made to improve surface finish by reducing the vibration of cutting tool in Lathe using viscoelastic material PTFE and Polyamide 66 or Nylon 66 liners fitted at the base of tool holder. 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) rpm, 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 (750,500,350,275 rpm), federate (0.2,018,0.16,0.14 mm/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 Taguchiorthogonal

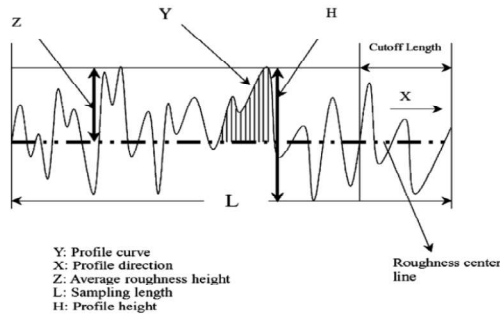
array to conduct experiments in an organized manner. Analysis of variance (ANOVA) with Minitab 17 software is performed to optimize the parameters on turning operation. The result indicates that Surface finish is observed to improve with application of Nylon liner.

**Keywords:** Surface Roughness, EN8K, PTFE, Nylon, Design of Experiment, Taguchi, ANOVA, Minitab 17, etc

## 1) 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]

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

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.

## 2) 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 finishes are used as measured output parameters. The Vibration parameters like

displacement ( $\delta$ ), velocity ( $V_e$ ), 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.

## 3) 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 ( $\delta$ ), velocity ( $V_e$ ), 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. 0

## 4) 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.

## 5) Project Objective:

The objective is to investigate the effect of Turning of EN8K steel using PTFE / Nylon 66 Liners for Carbide Insert Cutting Toolson 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.

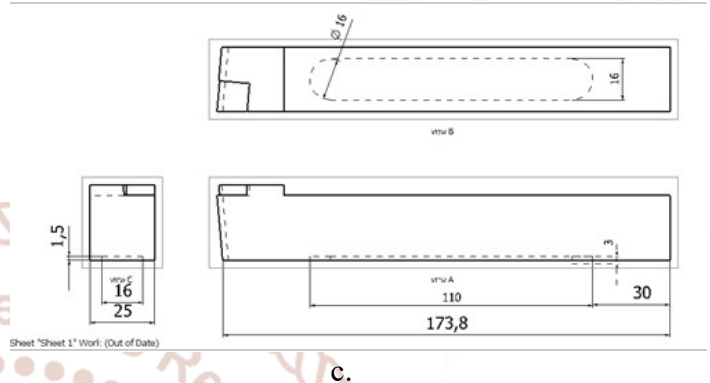
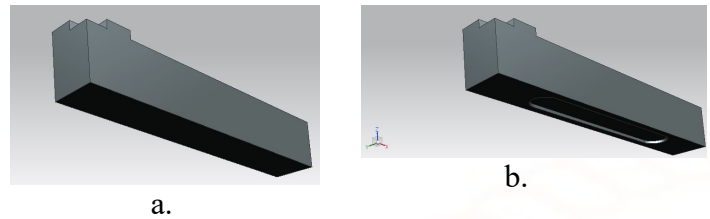
**6) EXPERIMENTAL SETUP:**

**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**

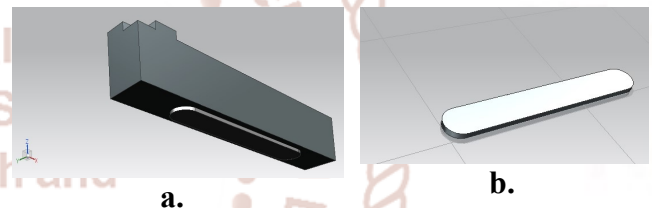
Work Piece Material	EN8K Steel
Length of the Work Piece	100 mm
Dia. of the Work Piece	50 mm



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

**Table No: 2 Chemical Composition of EN8 Steel**

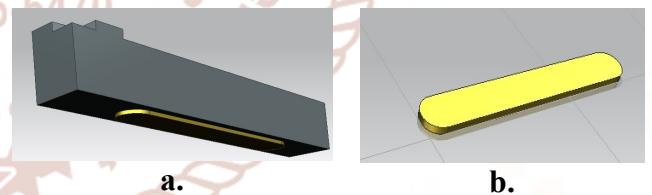
Std	Grade		C	Mn	Si	P	S
BS 970	EN8/080M40	Min	0.35	0.60	0.05	0.015	0.015
		Max	0.45	1.00	0.35	0.06	0.6



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

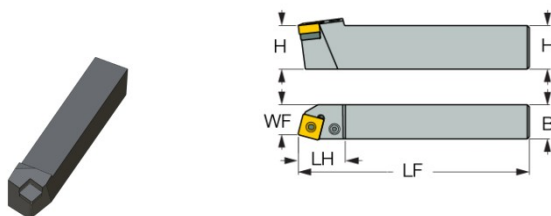
**Table No: 3 Physical Properties of EN 8 Steel**

Maximum stress	850 N/mm <sup>2</sup>
Yield stress	465 N/mm <sup>2</sup>
Elongation	16%
Proof Stress(0.2%)	450 N/mm <sup>2</sup>
Density	7.87gm/cm <sup>3</sup>



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

**Tool Holder:**



**Fig.2. Tool Holder**

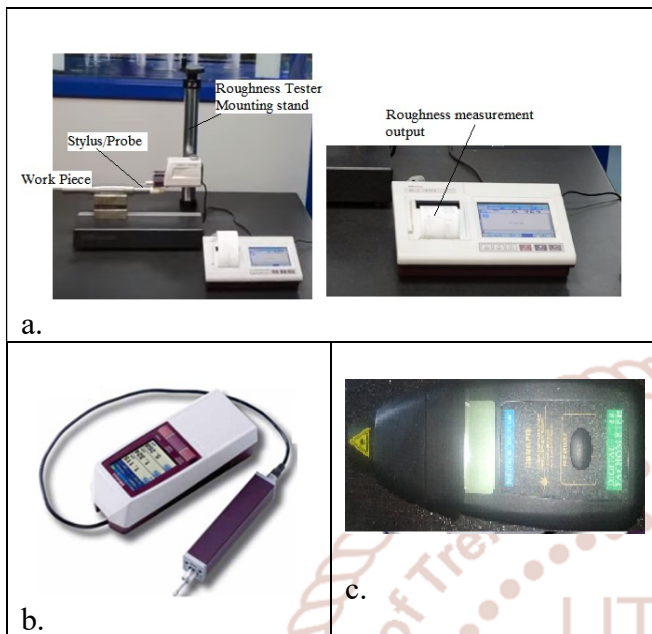
**Machine Tool Used:**



**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

**7) EXPERIMENTAL RESULTS OF PTFE**

**Table 5 Results of experiment with PTFE**

Std. order	Speed rpm	Feed mm/rev	DoC mm	Ra $\mu$ m	Rt $\mu$ m	Rz $\mu$ m
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

### 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.

### Effect Of Process Parameters On Surface Roughness (Ra)

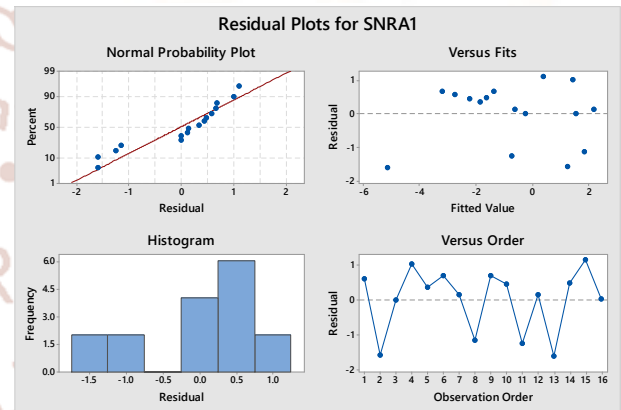


Fig 9 Residual plots for S/N ratios of Ra

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.

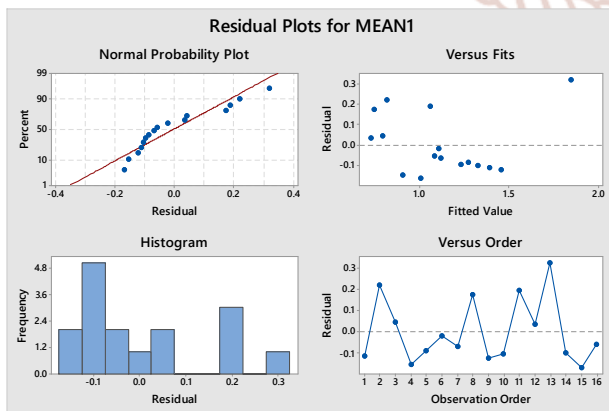


Fig 8 Residual plots for mean Ra

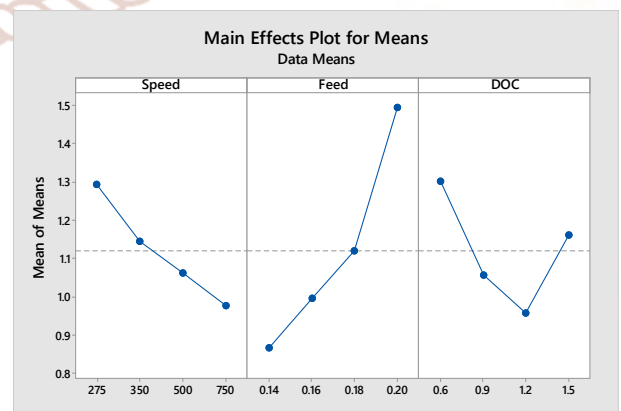
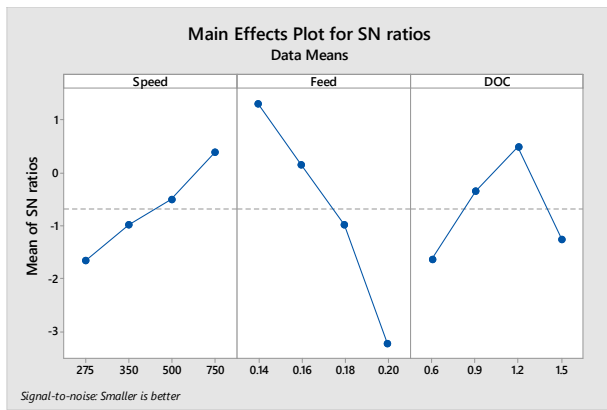


Fig 10 Response Main effects plot of Means of Ra



**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 6: 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 7: 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 11, shows the S/N ratio plots for Ra. It is clear from Figure 11, highest S/N ratio First level of Speed (750 rpm), Fourth level of Feed (0.14 mm/rev), second level of DOC (1.2mm) Therefore, the optimal setting of process parameters which yield maximum surface finish is A<sub>1</sub>B<sub>4</sub>C<sub>2</sub>.

**8) EXPERIMENTAL RESULTS FOR NYLON**

**Table 8 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
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

#### Effect of Process Parameters On Surface Roughness (Ra)

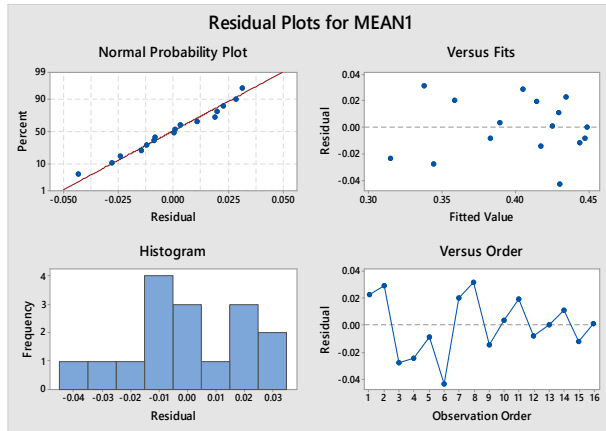


Fig 12 Residual plots for mean Ra

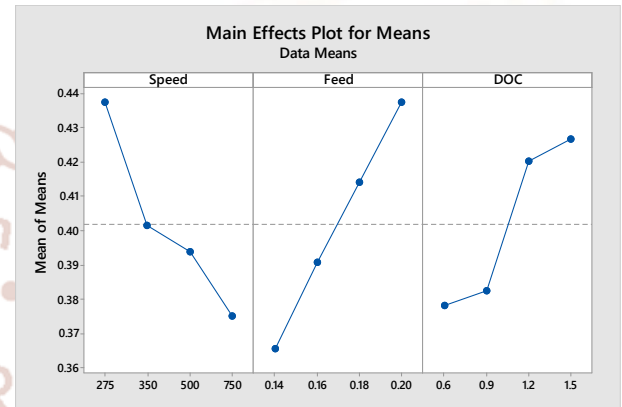


Fig 14 Response Main effects plot of Means of Ra

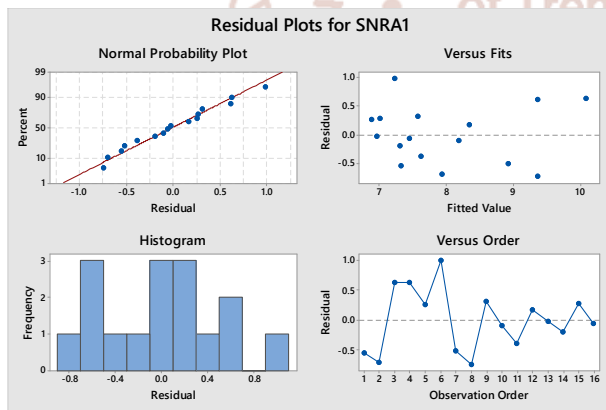


Fig 13 Residual plots for S/N ratios of Ra

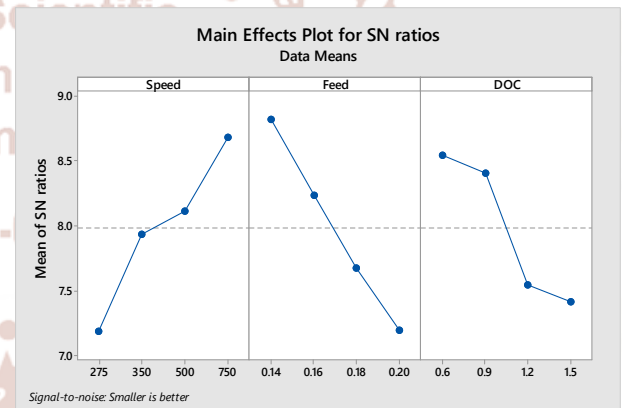


Fig 15 Response Main effects plot of SN ratios of Ra

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.

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	0.008170	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 9 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 10 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 15, shows the S/N ratio plots for Ra. It is clear from Figure 15, highest S/N ratio First level of SPEED (750 rpm), Fourth level of FEED (0.14 mm/rev), Fourth level of DOC (0.6 mm) Therefore, the optimal setting of process parameters which yield maximum surface finish is  $A_1B_4C_4$

**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 First level of Speed (750 rpm), Fourth level of Feed (0.14 mm/rev), Second level of DOC (1.2mm).

4. The optimal level of parameters are as follows for Nylon First level of Speed (750 rpm), Fourth level of Feed (0.14 mm/rev), Fourth level of DOC (0.6 mm).
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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