Experimental Investigation of Processes and Performance Parameters of turning operation on EN-31 Steel using Design of Experiment –A Taguchi Approach

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Abstract- *The manufacturing industry is constantly striving hard to decrease the cost and to increase the quality of the machine parts. This paper deals with selection of process parameters like speed, feed and depth of cut and the investigation performances of machining process responses like Surface Roughness, Material Removal Rate and selection of cutting insert using Design of Experiment (DOE). Experimental set up consists of low feed level (0.1mm/rev) and High feed level (0.15mm/rev) machining on Sliding Surfacing Screw Cutting Medium Duty Lathe Machine. In this research paper an attempt has been made to analyze the cutting condition to get predict Surface Roughness and Material Removal Rate in turning of EN-31 Steel rod using Cutting tool inserts are Tungsten coated and Copper coated TNMG 16 04 08 Triangular Geometry. The experiment was designed using Taguchi method L9 orthogonal array experimental run were conducted for various combination of cutting parameters. The orthogonal array and signal to noise ratio were employed MINITAB-15 Statistical Software and to study the practical responses at different condition. Experimental were carried out at various Process parameters are speed rate, depth of cut and constant two level of feed rate. To investigate the experimental results and concluded as follows Machining process investigates reveals that Copper Coated TNMG [16 04 08] inserts to give minimum value of Surface Roughness for low Feed Rate (0.1mm/rev). This investigation also reveals that Tungsten Coated TNMG [16 04 08] inserts to give maximum value of Material Removal Rate for low Feed Rate (0.1mm/rev). After comparison, it is observed that Copper Coated Inserts are better than that of Tungsten coated inserts for Surface Roughness and to achieve Maximum Material Removal Rate Tungsten coated inserts are better than that Copper coated inserts.*

Keywords- Turning Processes, Cutting tool, Surface Roughness (Ra), Material Removal Rate (MRR), Selection of Cutting Inserts, EN-31 Material, Design of Experiment (DOE).

I. INTRODUCTION

In the last three decades, there has been immense technical revolution in the manufacturing segment manufacturing industries [1]. In today's global manufacturing environment, all the companies are competing to produce high quality product at lowest cost. Turning is the most common machining operation which is specially being used for the finish of machining parts. In a typical operation, certain machine parts may require specified surface roughness. It is important parameter in mechanical applications that influence widely the performance of the parts and it is one of the major quality attribute of the machine parts. In turning operation, it is crucial task to select cutting parameters for achieving on the basis of experience. The present research work describe about how to select the controlled factor (spindle speed, depth of cut and constant feed rate) that can minimize the effect of noise factor on the response (surface roughness). In order to analyze the response of the system experiment were carried out for various spindle speed, depth of cut and constant feed rate. To decrease the number of runs, Taguchi orthogonal array of design was used instead of full factorial design. Thus, the paper is organized in the following manner. Firstly, an overview and previous studies to the relevant work has been discussed. Then experimental set up and data collection systems along with their technical specification have been discussed. In the next section, procedure experimental data collection and the data tables to the relevant work are included. After that the analysis of the collected data is discussed using Taguchi approach and their prediction and validated runs are performed to check the accuracy of the experimental set up. Finally, the paper concludes with a summary and discussion of this paper.

II. LITERATURE REVIEW

Harjot Singh [3] Discuses an investigation into the use of Taguchi Parameter Design for optimizing surface roughness generated by a conventional lathe. Control parameters being consider in this paper are cutting speed, feed rate and depth of cut. After experimentally turning sample work pieces using the selected orthogonal array and parameters. This study expected to produce an optimum combination of controlled parameter for the surface roughness. H. K. Dave et. al [4] presented an experimental investigation of the machining characteristics of different grades of EN materials in CNC turning process using TiN coated cutting tools. They focused on the analysis of optimum cutting conditions to get the lowest surface roughness and maximum material removal rate in CNC turning of different grades of EN materials by Taguchi method. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in dry turning operation. ANOVA has shown that the depth of cut has significant role to play in producing higher MRR and insert has significant role to play for producing lower surface roughness. Sahoo et al. [5] studied for optimization of machining parameters combinations emphasizing on fractal characteristics of surface profile generated in CNC turning operation. The authors used L27 Taguchi Orthogonal Array design with machining parameters speed, feed and depth of cut on three different work piece materials viz. aluminum, mild steel and brass. It was concluded that feed rate was more significant influencing surface finish in all three materials. It was observed that in case of mild steel and aluminum feed showed some influences while in case of brass depth of cut was noticed to impose some influences on surface finish. The factorial interaction was responsible for controlling the fractal dimensions of surface profile produced in CNC turning. Ashish Bhateja, et al [6],the first objective of this paper is selection of cutting tool & work tool material & geometry, selection of various process and performance parameters after parameter selection aims to study various techniques for the optimization for that purpose literature review and industrial survey is conducted. The process and machining parameters for the performance characteristics of turning operation on CNC using different grades of Tungsten Carbide and with varying properties & surface roughness testing of work piece material to be carried out after machining. After testing optimization and compare the Effect of cutting parameters on surface roughness of different selected geometry on EN-24 alloy steel by using empirical approach i.e. Taguchi Analysis using Statistical Software. In the end also aims to calculate Tool Wear Rate (TWR) & Material Removal Rate (MRR) related with the performance parameters based upon the experimental investigation. In the first step of step turning the roughness value for TNMG is least, showing the optimal value.

III. METHODOLOGY

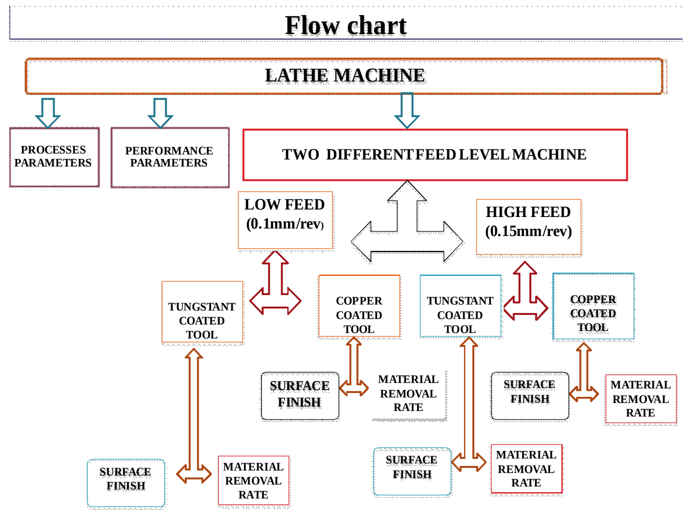

Figure 1. Flow chat of processes

1. Material and its specification

The work pieces material for this experiment was EN-31 Steel. It is the commonly used in industries for Manufacturing cutting Tools like Drill bit, Sub land drill, Reamer, Tap. Mechanical properties and chemical composition of EN-31 steel shown in table 1and table 3 respectively. The work piece was cut from 300 mm long and 50 mm diameter.

2. Experimental Design and Setup

This experiment involves a basic Taguchi design in which Orthogonal array design is used to perform experimental run at various cutting parameters. The experiment involves three controlled factors are spindle speed depth of cut and constant feed rate while the responses variable are surface roughness, material removal rate and selection of cutting inserts. As shown in Table 3 all the three Control factors i.e. Spindle speed, depth of Cut has three levels and two constant feed levels. These results in total of 9 randomized run to be conducted to test all the combination of the parameters level according to Taguchi L9 orthogonal array design as shown in Table 4 all the required data collected from the experimental setup for individual run. The experiment was performed using Sliding Surfacing Screw Cutting Medium Duty conversational Lathe Machine. The major technical specification

Table 1. Mechanical properties of EN-31 Steel Material

Sr. No.	Properties	Values
1	Tensile Strength	750 N/mm²
2	Yield Stress	450 N/mm²
3	Reduction of Area	45%
4	Elongation	30%
5	Modulus of elasticity	215000 N/mm²
6	Density	7.8 Kg/m3
7	Hardness	63 HRC
8	Hardening Temperature	8020C - 8600C
9	Quenching medium	Oil
10	Tempering temperature	1800C - 2250C
11	Brinell- Rock well hardness no	59-65

Table 2. Experimental Levels of cutting parameters

Cutting Parameters	No. of Levels	Values for Each Level level1	level 2	level 3
SS (rpm)	3	265	400	600
DOC (mm)	3	0.5	1.0	1.5
Constant FR (mm/rev)	0.1 mm /0.15 mm	0.1 mm /0.15 mm		

SS: Spindle speed; DC: Depth of cut; FR: Constant Feed rate Selected parameters values were set and data were recorded for future work. The Machining processes was conducted use a new Triangle Geometry Tungsten Coated and copper coated TNMG [16 04 08] inserts.

Table 3. Composition of EN-31 Steel Material

Mark	C %	Si %	Mn %	P%	S%	Cr%
En-31	1.30	0.30	0.50	0.024	0.025	1.40

Table 4. L9 Design of experiment Taguchi Analysis

$L_9(3^2)$ Orthogonal array				
	Independent variables			Performance parameters value
Exp	Variable 1	Variable 2	Variable 3	
1	1	1	1	P1
2	1	2	2	P2
3	1	3	3	P3
4	2	1	2	P4
5	2	2	3	P5
6	2	3	1	P6
7	3	1	3	P7
8	3	2	1	P8
9	3	3	2	P9

Table 5. Technical Specification of Lathe Machine

Sr.No.	Specifications	Range
1	Length of Bed	1350 mm./
2	Admit Between Centre	522 mm.
3	Height of Centre	215 mm.
4	Width of Bed	270 mm.
5	Spindle Bore	52 mm.
6	Spindle Nose Dia/Threads	74.3 x 6
8	No. of Spindle Speed/Range	6/40 to
9	Swing over Cross Slide	230 mm.
10	Swing over Bed	415 mm.
11	Tail Stock Spindle Morse	MT - 4/50
12	No of Threads / Pitch	TPI 2 to

After final finish cut the surface roughness was measure of Work piece at each 900 incremental interval along the circumference as shown in figure 2. The measured value was taken using Mitutoyo Surface Roughness measuring tester SJ-210 as shown in figure 3. The measurements were obtained with the help of movement of stylus with diamond tip over the surface along the Z axis. The instrument measured various forms Surface roughness amplitudes according to the particular Industrial use i.e. Arithmetic mean of roughness(Ra).

3. Experimental procedure

A randomize schedule of run was created at various combination according to Taguchi Design of experiment as shown in Table 4. The work pieces from the bar were cut and turned with specified cutting condition. After completion of all the runs, the surface roughness and material removal rate was measured. Surface roughness was measured at around the circumference and material removal rate was measured by using weaning machine and finally their average value stored in the data table. Data processing and its analysis were performed through MINITAB-15 statistical software

IV. ANALISIS OF S/N RATIO

For Taguchi analysis, experimental results of surface roughness and material removal rate are transformed into Signal to Noise (S/N) ratio as shown in table-8 and table -9 here signal is representing the desirable value i.e. mean of the output characteristic while the noise prescient the un desirable value i.e. secured deviation of

Table 6. Taguchi Design analysis Response variable of Surface Roughness of Copper Coated Tool at low feed rate (0.1mm/rev).

Ss (Rpm)	Fr (Mm/Rev)	Doc (Mm)	(Ra) (µm)	Snra	Mean
265	0.1	0.5	0.15	17.721	0.15
265	0.1	1.0	2.50	-	2.50
265	0.1	1.5	2.94	-	2.94
400	0.1	1.0	1.69	-	1.69
400	0.1	1.5	0.73	2.7335	0.73
400	0.1	0.5	0.14	17.077	0.14
600	0.1	1.5	1.83	-	1.83
600	0.1	0.5	0.16	15.917	0.16
600	0.1	1.0	1.35	-	1.35

Table 7. Taguchi Design analysis Response variable of Material Removal Rate of Tungsten Coated Tool at low feed rate (0.1 mm/rev)

SS (rpm)	FR (mm/rev)	DOC (mm)	MRR (gm/sec)	SNRA	MEAN
265	0.1	0.5	13	22.2789	13
265	0.1	1.0	48	33.6248	48
265	0.1	1.5	23	27.2346	23
400	0.1	1.0	46	33.2552	46
400	0.1	1.5	22	26.8485	22
400	0.1	0.5	7	16.9020	7
600	0.1	1.5	15	23.5218	15
600	0.1	0.5	5	13.9794	5
600	0.1	1.0	25	27.9588	25

For this Experimental analysis, the first categories“The smaller is better” was employed to calculate S/N ratio and its main effects plots are generated for S/N Ratio using Minitab-15 statistical software as Shown in figure 4. And the second categories “The larger is better” was employed to calculate S/N ratio and its main effects plots are generated for S/N ratio using Minitab-15 statistical software as shown in figure 5. The first category was chosen to obtain the optimum condition for minimization of surf ace roughness and second category was selected to obtain maximization of Material removal rate Which is the desired condition for turned machine parts? The following equation was used to calculate S/N ratio

(A) Smaller- the- better

$S/N = -10 \log n-1(\sum y2)$

(B) Larger-the-better

$S/N= -10 \log n-1(\sum 1/y2)$

Where n is the no .of repetition of the experiment and y is the measured value of the quality characteristics.

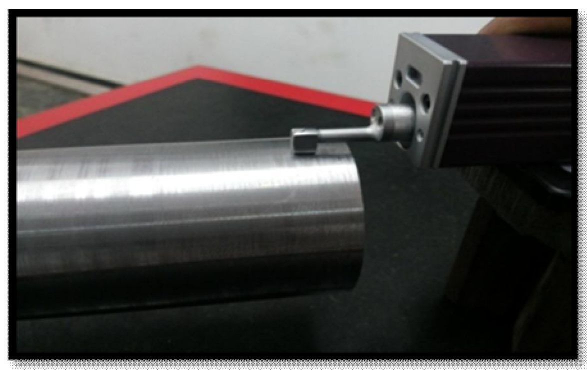

Figure 2. Measurement section of surface roughness

Figure 3. Mititoyo surface Roughness Tester SJ-210

While applying Taguchi design analysis to theses experimental data, the data table for analysis of S/N ratio was generated as shown in Table 8 by which rank value of the factors can be obtained for S /N ratios.

Table 8. Response Table of surface roughness and the values of S/N Ratios at Low feed rate (0.1 mm/rev) Copper coated tool.

Level	Ss (Rpm)	Fr (Mm/Rev)	Doc (Mm)
1	0.1318	2.6345	16.9054
2	5.0844		-5.0411
3	2.6873		-3.9608
DELTA	4.9526	0.0000	21.9465
RANK	2	3	1

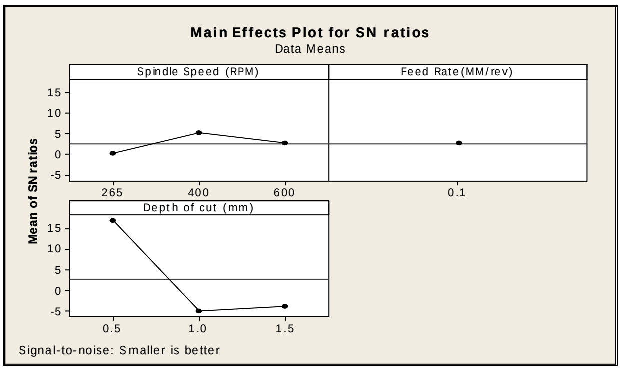

Figure 4. S/N ratios vs. cutting parameters (SS, DOC, FR) Plots

Table 9. Response Table of Material Removal Rate and the values of S/N Ratios at Low feed rate (0.1 mm/rev) Tungsten Coated tool

Level	Ss (Rpm)	Fr (Mm/Rev)	Doc (Mm)
1	27.71	25.07	17.72
2	25.67		31.61
3	21.82		25.87
DELTA	5.89	0.00	13.89
RANK	2	3	1

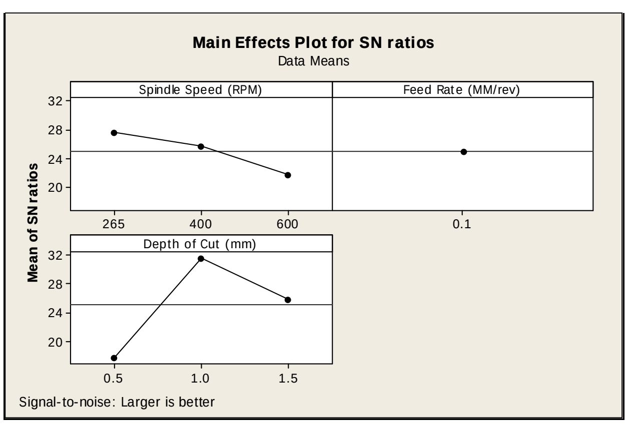

Figure 5. S/N ratios vs. cutting parameters (SS, DOC, FR) Plots

Table 10. value of Surface Roughness (Ra) for two different Tool at low feed rate

DEPTH OF CUT	TUNGSTEN COATED TOOL	COPPER COATED TOOL
0.5	1.54	0.13
1.0	1.37	1.35
1.5	1.54	0.73

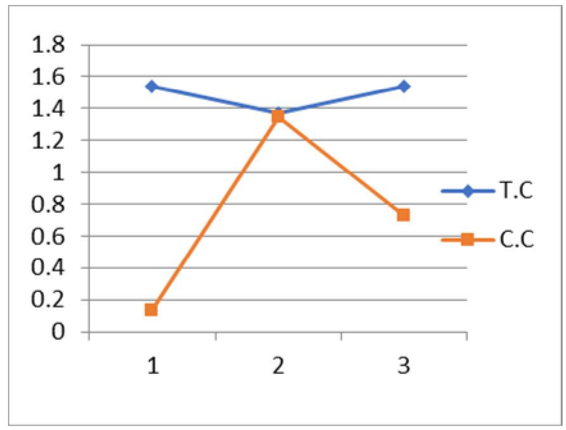

Figure 6. Comparison of surface Roughness for two different tools

Table 11. value of Material Removal Rate for two different Tool at low feed rate

DEPTH OF CUT	TUNGSTEN COATED TOOL	COPPER COATE TOOL
0.5	13	10
1	48	33
1.5	23	42

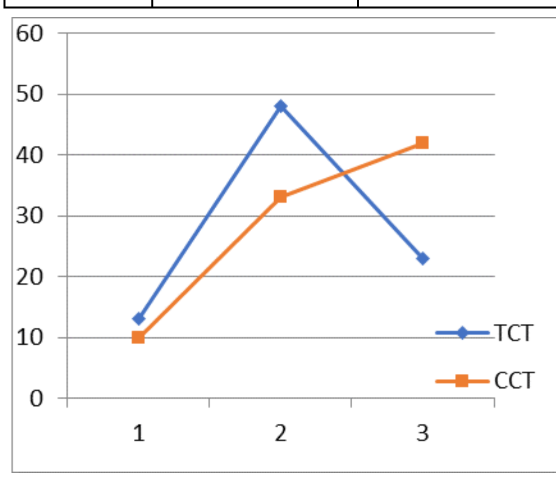

Figure 7. Comparison Material Removal Rate for two different tools

V. CONCLUSION

EN-31 steel material is used as cutting tool in huge amount to make a cutting tools like Drill bit, Tap, Reamer cutter etc. For that sliding surfacing screw cutting lathe machine carried out for turning operation. The turning processes by using experimental set up to select processes parameters Speed Rate, Depth of Cut, Feed Rate is constant and to get responses Surface Roughness and Material Removal Rate by using Design of Experiment Taguchi's method. Machining process investigation reveals that Copper Coated TNMG [16 04 08] Inserts give minimum value of Surface Roughness for low Feed Rate (0.1mm/rev). So now, finally we decide that the best combination is [A2-400 rpm], [C1-0.5 mm], A2C1 i.e. Smaller is better. It also reveals that Tungsten Coated TNMG [16 04 08] inserts give maximum value of Material Removal Rate for low Feed Rate (0.1mm/rev). So now, finally we decide that the best arrangement is [A1-265 rpm], [C2-1.0 mm], A1C2 i.e. Maximum is better. After comparison, finally it is concluded that Copper coated inserts are better than that Tungsten coated inserts for Surface Roughness and to reach Maximum Material Removal Rate, Tungsten coated inserts are better than that of Copper coated inserts.

VI. FUTURE SCOPE

Cutting fluid can be aimed on to the cutting edge to reduce temperature of tool tip and surface roughness. Coolant can be supplied constantly while the insert is engaged in cut. A coolant adapter can be fixed with the supply directed from above. By doing modifications in the future for tool block with a cutting insert, the coolant supply can be linked above the block.

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