OPTIMIZATION OF SURFACE ROUGHNESS PARAMETERS IN TURNING EN1A STEEL ON A CNC LATHE WITH COOLANT

Girish Tilak[1], Pavan P Kadole[2], N.Lakshmana Swamy[3]

[1]GirishTilak Assistant Professor, Department of Automobile Engineering, New Horizon College of Engineering, Karnataka, India
[2]Pavan P Kadole Assistant Professor, Department of Mechanical Engineering, New Horizon College of Engineering, Karnataka, India
[3]N. Lakshmanaswamy Professor, Department of Mechanical Engineering, University Visveraya College of Engineering, Karnataka, India

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Abstract - *This paper presents the optimization of surface roughness parameters in turning EN1A steel on a CNC lathe with coolant. The optimization of machining processes is essential for the achievement of high responsiveness of production, which provides a preliminary basis for survival in today's dynamic market conditions. The quantitative determination of Surface Roughness is of vital importance in the field of precision engineering. Machinability can be based on the measure of Surface Roughness. Surface Roughness depends on the factors such as Speed, Feed and Depth of Cut. In this work, the Taguchi methods, a powerful statistical tool to design of experiments for quality, is used to find the optimal cutting parameters for turning operations. Analysis of Variance has been used to determine the influencing parameters on the output responses. Using Taguchi technique, we have reduced number of experiments from 27 to 9 there by the total cost of the project is reduced by 66.66%. The results obtained are encouraging and the concluding remarks are helpful for the manufacturing industries.*

Key Words: surface roughness, Taguchi method, with coolant, parameters.

1.INTRODUCTION

Turning is the removal of material from the outer diameter of a rotating cylindrical work piece by means of single point cutting tool which is held stationary on the tool post and moved parallel to the work piece axis with suitable Speed, Feed and Depth of Cut, Turning is used to produce cylindrical surface on the work piece. In turning the diameter of the work piece, usually to a definite dimension and the length of the work piece remains same.

1 TURNING OPERATION

1.1Cutting Factors In Turning

The important factors in turning operation are speed, feed, and Depth of Cut. Other factors such as type of work piece material and type of tool have a large influence, of course, but these can be changed by operator by regulating the controls at the machine.

Speed refers to the spindle rotation and the work piece. The revolutions per minute (rpm) it expresses their rotating speed. Feed denotes to the cutting tool, rate at which the tool goes lengthways its cutting path. On most power-fed lathes, the feed rate is directly associated to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev. Depth of Cut is the width of the film being removed in one pass from the work piece or the distance from the uncut surface of the work to the cut surface, and it is expressed in mm.

1.2Characteristics of EN1A Steel

EN 1A steel isa alloy steel that is alloyed with a variation of elements in total between 1.0% and 50% by weight to strengthen the mechanical properties. Alloy steels are divided into two groups: low-alloy steels and high-alloy steels..

1.3 Cutting Fluids

Cutting fluids are used in many metal-cutting operations, as well as grinding, to maintain optimum production rates by minimizing tool wear and improving surface finish. In most cases the cost of the fluid, which is usually re-circulated, is negligible compared to the benefits obtained. Figure 1.1 shows the effect of coolant in changing the chip thickness and shear angle.

1.4 Surface Roughness

Surface roughness is one of the main factors in evaluating the quality of a component as it affects all the dimensions of quality mentioned above. Since it is a important factor of quality it has received solemn attention for many years. It has formulated an important design feature in many circumstances such as parts subject to fatigue loads, precision fits, fastening and aesthetic requirements. Surface roughness inflicts one of the most critical restraints for machine selection and cutting parameters.

1.5 Taguchi Technique

Genichi Taguchi is a Japanese engineer who has been involved in the improvement of Japan's manufacturing products and processes since 1940. He has established the philosophy and method for process or product quality enhancement that depends profoundly on statistical conceptions and tools, especially statistically designed experiments. Taguchi's major involvement has combining engineering and statistical techniques to achieve fast enhancements in cost and quality by optimizing product design and manufacturing processes.

2. EXPERIMENTAL PROCEDURE

2.1 Work Piece Material

EN 1A steel is categorized as Steel alloy. It can be seen in forms of extruded rod bar and wire and extruded shapes. It has strong resistance to corrosion. EN 1A steel is easily machinable and can have a wide variety of surface finishes. It is used in the field of structural engineering, building and architecture due to following advantages: i) Lower Weight. ii) Lower Maintenance cost. iii) Longer life. iv) Recycling.

2.2Cutting Tool

Cutting tool is used to removing the material from the work piece by means of shear deformation. Cutting tools must be made of a stronger material than the work piece material, and the tool must be capable of withstanding the heat generated during the metal-cutting process.
Insert Designation
The details of cutting insert TNMG 16 04 08 is mentioned below.

T: Insert Shape= Triangle 600
N: Clearance Angle= 00 No rake
M: Medium Tolerance= d+/-0.05 m+/-0.08 s+/-0.13
G: Insert Type (Pin / Top holding double sided)
16: means length of all cutting edge is 16 mm
04: standpoints for nominal thickness of the insert is 4 mm
08: standpoints for nose radius is 0.8mm

2.3Profilometer

A diamond stylus is moved perpendicularly in interaction with a model and then moved sideways across the model for a stated distance and stated contact force. A Profilometer is capable of measuringvery small surface differences in perpendicular stylus movement. A typical Profilometer can measure small vertical features ranging in height from 10nm to 1mm. The stature position of the diamond stylus produces an analogue signal which will be converted into a digital signal and then stored, analyzed and shown. The radius of diamond stylus ranges from 20nm to 25μm, and the flattenacity is controlled by the scan speed and data signal sampling degree. The stylus tracing force ranging from 1 to 50 mg.

2.4 Experimental Procedure

Optimization of Machining Parameters (3 factors and 3 level analyses) and studies on Surface Roughness, MRR and Machining Time using TNMG 16 04 08 with Coolant in CNC lathe (ACE) using L9
In this experiment the turning operation was done on the work piece i.e., EN 1A Steel (Length 100 mm and Diameter 20 mm) on a CNC lathe. TNMG 16 04 08 Insert was used for turning. 3 factors were selected i.e., Speed (rpm), Feed (mm/rev) and Depth of Cut (mm) at 3 levels i.e., (Minimum, Average and Maximum) and coolant was used.

To find Minimum number of experiments to be conducted
For 3 Factors and 3 Levels, the minimum number of Experiments to be conducted is shown in the following

Table -1: Factors, Levels and Degrees of Freedom

Factor Code	Factor	No of Levels	Degrees of Freedom
A	Speed	3	2
B	Feed	3	2
C	Depth of Cut	3	2
	Total Degrees of freedom		6
	Minimum number of Experiments		7

Table -2: Standard L9 Orthogonal Array

Trial No.	Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table -3: Orthogonal Array with Observations with Coolant

Trial No	Turning Parameter			Output Responses						
	A Cutting Speed (rpm)	B Feed (mm/rev)	C Depth Of Cut (mm)	Surface Roughness, Ra (μm)	Weight of specimen Before Turning (gm)	Weight of specimen After Turning (gm)	Machining Time (actual), t (sec)	Machining Time (theoretical), t (sec)	MR R(a) (mm^3/min)	MR R(t) (mm^3/min)
1	1000	0.1	0.2	2.74	197.301	182.914	49	39	2624.49	1200
2	1000	0.2	0.4	3.85	197.301	180.613	30	21	7237.59	7500
3	1000	0.3	0.6	3.91	197.301	179.305	24	18	14796.70	16800
4	2000	0.1	0.4	3.32	197.301	181.12	26	20	7990.47	7400
5	2000	0.2	0.6	3.43	197.301	179.095	17	22	19000	22600
6	2000	0.3	0.2	3.46	197.301	184.003	13	20	11526.78	11800
7	3000	0.1	0.6	2.42	197.301	178.564	19	28	14961.54	17200
8	3000	0.2	0.2	3.35	197.301	183.381	13	21	13214.28	12800
9	3000	0.3	0.4	3.41	197.301	181.700	11	17	23214.28	33400

3. RESULTS AND DISCUSSION

Studies Related to Surface Roughness with Coolant

The following studies were conducted associated with Surface Roughness
1.Regression Model For Surface Roughness.
2.General Linear Model for Surface Roughness.
3.Analysis of Variance For Surface Roughness.
4.Response Table of Signal to Noise Ratios for Surface Roughness.
5.Graph showing the Main Effects plot for S/N ratios of Ra.

3.1 Regression Model For Surface Roughness

Regression Equation is the relationship between dependent variable and one or more independent variables. Dependent variable is the Surface Roughness and independent variables are Speed, Feed and Depth of Cut.
Regression Model has been developed by using MINITAB software.
The regression equation is

Surface Roughness (μm) = 2.92 - 0.000220 Speed (rpm) + 3.83 Feed(mm/rev)+ 0.175 Depth of Cut (mm)---Equation 1

If the value of Speed (m/min), Feed (mm/rev) and Depth of Cut (mm) are known, using the above equation we can foresee the corresponding Surface Roughness value (μm).

3.2General Linear Model for Surface Roughness

Table -4: General Linear Model for Surface Roughness

Factor	Type	Levels	Values
Speed(rpm)	Fixed	3	1000,2000,3000
Feed(mm/rev)	Fixed	3	0.1,0.2,0.3
Depth of Cut(mm)	Fixed	3	0.2,0.4,0.6

General Linear Model for Surface Roughness is shown in Table 4.Input Parameters for this experiment are Speed, Feed and Depth of Cut at 3 levels and the values are shown in the above Table.

3.3Analysis of Variance for Surface Roughness

Table -5: Analysis of Variance for Surface Roughness

Source	DF	Seg SS	Adj SS	Adj MS	F	P	RANK	Contribution
Speed (m/min)	2	2.412	2.412	1.2061	1.57	0.388	**2**	**18.98%**
Feed (mm/rev)	2	8.686	8.686	4.3430	5.67	0.150	**1**	**68.56%**
Depth of Cut (mm)	2	1.573	1.573	0.7865	1.03	0.493	**3**	**12.46%**
Error	2	1.532	1.532	0.7662				
Total	8	14.204			8.27			**100%**

For the experiment, Analysis of Variance wasdone (Shown in Table 5) to find the effect of Machining parameters on the output Responses using MINITAB software. Input parameters taken into consideration were Speed, Feed and Depth of Cut. Surface Roughness was considered to be output parameter. Ranking is given based on the value of P (Smaller the value of P, Greater the influence of that parameter on the Output). For the experiment, the input parameters that are influencing the Output parameter (Surface Roughness) in descending order are Feed, Speed, and Depth of Cut. According to the table 5. Feed has the highest contribution of 68.54% followed by Speed 18.98% and Depth of Cut 12.46%.

3.4Response Table for Signal to Noise Ratios

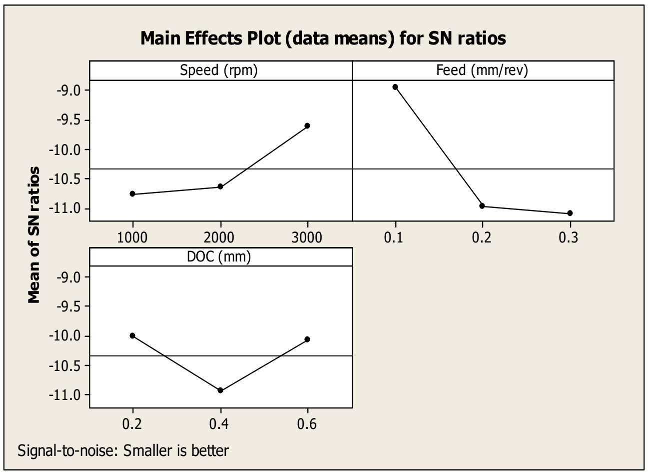
Table -6: Analysis of Variance for Surface Roughness

Levels	Speed (rpm)	Feed (mm/rev)	Depth of Cut (mm)
1	-10.769	-8.951	-10.012
2	-10.637	-10.972	-10.929
3	-9.611	-11.093	-10.075
Delta	1.158	2.142	0.917
Rank	**2**	**1**	**3**

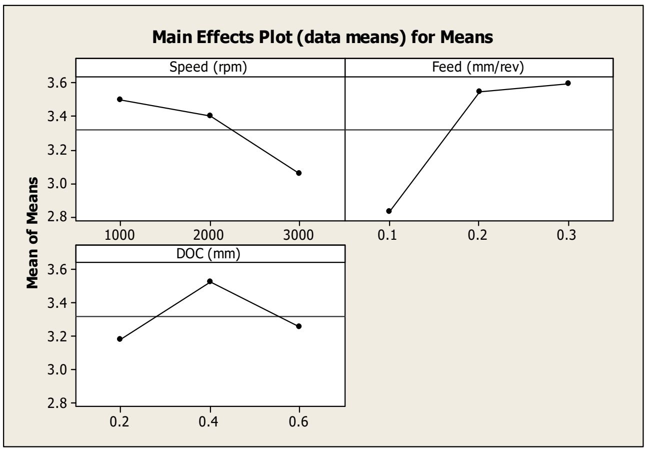
Table 6. shows the Response for Signal to Noise Ratios of the specified parameters. For this experiment, the input parameters that are influencing the Output parameter (Surface Roughness) in their descending order are Feed, Speed, and Depth of Cut. Response Table is used to cross check the ranking obtained in the Analysis of Variance.

3.5Graph Showing the Main Effects Plot for S/N Ratios of Ra

Highest S/N ratio gives optimum machining parameter. Hence it can be observed that optimum values of machining parameters to get minimum Surface Roughness are Speed (3000 rpm), Feed (0.1mm/rev) and Depth of Cut (0.2mm). Confirmation Test: Turning was conducted at optimum cutting parameters i.e., Speed 3000 rpm, feed 0.1mm/rev and Depth of Cut 0.2mm and found that Surface Roughness as 1.37 µm.

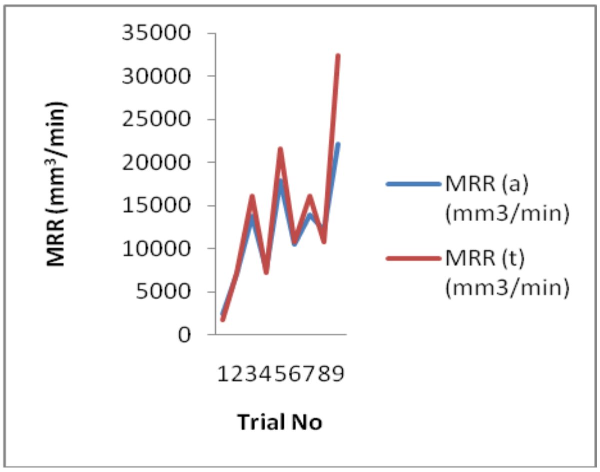


Graph -1: S/N ratio values for Surface Roughness



Graph -2: Mean values for Surface Roughness

3.6To Study the Comparison of Actual and Theoretical Values of Mrr



Graph -3: Comparison of Actual and Theoretical values of MRR

From Graph 3, it can be seen that for all the trials of this Experiment, Theoretical value of Material Removal Rate is more compared to Actual values of Material Removal Rate. Further it can be observed that Material Removal Rate is Maximum when the values of Speed, Feed and Depth of Cut are at maximum levels i.e., 3000 rpm, 0.3 mm/rev and 0.4 mm respectively. Also it can be observed that Material Removal Rate is Minimum when the values of Speed, Feed and Depth of Cut are at minimum levels i.e., 1000 rpm, 0.1 mm/rev and 0.2 mm respectively.

3. CONCLUSIONS

Following is the summary drawn based on the experiment conducted on EN 1A Steel alloy during Turning operation with Uncoated Carbide Inserts with Coolant.

1.Regression Model has been developed for Surface Roughness with coolant relating Speed, Feed and Depth of Cut to predict the value of the surface roughness.
2.The Analysis of Variance was performed to identify the influence of Machining Input parameters considered were Speed, Feed and Depth of Cut on the output Responses Surface Roughness using MINITAB software. Based on the Analysis of Variance the input parameters that are influencing the Output parameter Surface Roughness in their descending order are Feed, Speed and Depth of Cut.
3.Feed has the highest influence of 68.54% followed by Speed 18.98% and Depth of Cut 12.46%.
4.The optimum values of machining parameters to get Optimum Surface Roughness are Speed of 3000 rpm, Feed of 0.1mm/rev and Depth of Cut of 0.2mm.Surface Roughness is found that is 1.37 µm. And average Surface Roughness is found to be 3.32 µm.
5.Improvement of Surface Roughness by 29.34% at the optimum values and by 10.27% at the average after using the coolant
6.The Material Removal Rate is Maximum i.e., 23214.28 mm3/min when the values of Speed, Feed and Depth of Cut are 3000 rpm, 0.3 mm/rev and 0.4mm respectively. And Machining Time is 11 sec i.e., Minimum at this level.
7.The Material Removal Rate is Minimum i.e., 2624.49 mm3/min when the values of Speed, Feed and Depth of Cut are 1000 rpm, 0.1 mm/rev and 0.2 mm respectively. And Machining Time is 49 sec i.e., Maximum at this level.
8.The average Material Removal Rate is 12729.57 mm3/min after using the coolant. Improvement of Material Removal Rate by 1.48% at the average.

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BIOGRAPHIES

I GirishTilak Assistant Professor working in the Department of Automobile Engineering in NHCE Bangalore. I'm interested in the field of Manufacturing Science.

Pavan P Kadole Assistant Professor working in the Department of Mechanical Engineering in NHCE Bangalore. I'm interested in the field of Manufacturing Science.

Dr. N. Lakshmanaswamy is professor working in the Department of Mechanical Engineering, UVCE Bangalore. He is interested in the field of Manufacturing Science.