Optimization of Material Removal Rates for CNC Turning of MS and EN-31 Using Taguchi Method

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Abstract: Machining is usually the final stage of product development and can be performed by using conventional as well as non conventional machining methods. In present research work machining using CNC turning operation is performed on two materials used in product development, first material is (MS) mild steel and second is EN-31 (steel) which are frequently used in small and large scale business enterprises. The design of experiment table is set by using mixed Taguchi method and total 18 experiments were performed on CNC lathe machine. Response variable is selected which is material removal rate (MRR). L18 Mixed Taguchi array based experiments were conducted in CNC Supertech 6.2 turning centre using carbide insert CNMG 120408. The individual and interaction effects of cutting speed (v), feed rate (f) and depth of cut (ap) on MRR. Non-Traditional optimization technique taguchi is used to find the optimum parameters in turning of MS and EN-31.

Keywords: CNC Lathe, DOE, Mixed Taguchi, Model Equation.

1. INTRODUCTION

Machining operations have been the central point of enchantment of the manufacturing industry since the upset of commercial enterprise. Quality and requirements of the client are the two main objectives that any manufacturing industry in the world tries to achieve. Machining is one of the main operations of metal processing in any manufacturing industry. The quality of the metal cut obtained depends on many parameters of the process. These process parameters affect the output response or performance. Machining of various materials endeavour hard either to accomplish a base cost of production or most extreme production rate or an ideal mix of both, alongside the better quality in machining.

Machining process Input parameters:

1. Machine tool (rigidity, capacity, accuracy, etc,)
2. Cutting tool (material, coating, geometry, nature of engagement with the work material, tool rigidity, etc,)
3. Cutting conditions (speed, feed and depth of cut).

Machining process Output parameters:

1. Cutting tool life/tool wear/tool wear rate
2. Cutting forces/specific cutting forces
3. Power consumption/specific power consumption

2. EXPERIMENTAL WORK

2.1 Turning Operation

The turning operation is an essential metal machining operation that is utilized generally in enterprises managing metal cutting. In a turning operation, a high-accuracy single point cutting device is solidly held in an apparatus post and is encouraged past a pivoting work piece in a course parallel to the hub of revolution of the work piece, at a steady rate, and undesirable material is expelled as chips offering ascend to a tube shaped or more intricate profile. This operation is completed in a Lathe Machine either physically under an administrator's supervision, or by a controlling PC program. There are two sorts of movement in a turning operation. One is the cutting movement which is the roundabout movement of the work and the other is the nourish movement which is the straight movement given to the device.

2.2 Machine Technical Specifications

The experiments are performed on CNC machine installed at CIPET, Jaipur. The machine is made by MAC-POWER, vertical lathe center (VX-135). For present research work dry flow condition is adopted because of mixed strength steel material. The technical specifications of this machine are present in table.

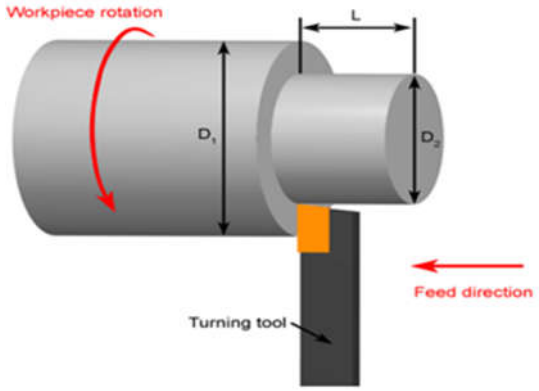

Figure 1 : Turning operation

Table 1.: Machine specification

1	Power Consumption of Motor	7.5 KW
2	Speed Variation in RPM	1000-5000 RPM
3	Guide ways	LM Type
4	Load capacity	2500 N
5	Feeding Speed	0.5 to 50 mm/min.
6	Electrical Power Supply	14 kVA, 3Phase

2.3 Tool Geometry

Most turning is finished utilizing a replaceable insert that is held in a turning instrument body, which is then mounted on the lathe turret. The fundamental design of CNC device is available in figure 2 Turning inserts utilize exceedingly designed composite structures, coatings, and geometry highlights to accomplish incredible precision and high material expulsion rates.

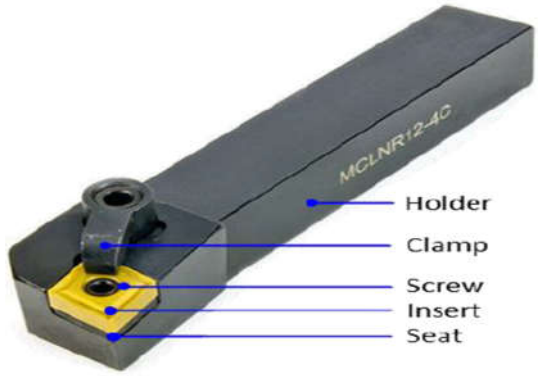

Figure 2 : Turning tool

2.4 Test Piece Materials

The work material used as test specimen is MS and EN-31 for Machinability assessment. The test specimens to conduct the experiment were prepared form 50 mm cylindrical bar stock. Each specimen having 50 mm in diameter and 70 mm in length were used for turning. The chemical composition of the material by percentage of weight basis is given in the Table 2 and Table 4 and the mechanical properties of MS and EN-31 are shown in Table 3 and Table 5.

Table 2 : Chemical composition of MS (Weight Basis)

Carbon	Silicon	Manganese	Sulphur	Phosphorus	Fe
0.16-0.18	0.30	0.70-0.90	0.030	0.040	Balance

Table 3 : Mechanical properties of MS

Sut (MPA)	Syt (MPA)	Young Mod (MPa)	Elongation	Density (kg/m3)
440	370	205*10^6	11%	7860

Table 4 : Chemical composition of EN-31 (Weight Basis)

Carbon	Silicon	Manganese	Sulphur	Phosphorus	Chromium	Fe
1.066	0.22	0.325	0.023	0.013	1.415	Balance

Table 5 : Mechanical properties of EN-31

Sut (MPa)	Syt (MPa)	Young Mod. (MPa)	Elongation	Density (kg/m3)
615	528	197*10^6	9%	7800

2.5 Methodology & Pilot Experiments:

Pilot experiments are performed for any research work to identify the levels of machine parameters, so in present research work pilot experiments are also performed and these experiments are help to identify the range of machining parameters for present research work. In following table the actual range of process parameters are present which is used for experimental table.

Table 6 : Pilot Experiments for present research work

S. No.	Factor	Range after Pilot Exp.
1	Feed Rate	0.2 to 1
2	Speed	1200 to 2000
3	Depth of Cut	0.3 to 1

2.6 Experiment Mixed Taguchi Array

In present research work mixed Taguchi method is applied for experimental table generation. Total four factors are selected from this research work. Among all factors one factor material has two levels, one level is MS and second level is EN-31, remaining factors has three levels, so it is required to use mixed Taguchi method for this research work. In mixed Taguchi method total 18 experiments are performed on CNC turning machine.

Table 7 : Orthogonal Array for present study

S.No.	A:Material	B: Speed (RPM)	C:Feed rate (mm/min)	D:DOC (mm)
1	1	1500	0.5	0.2
2	1	1700	0.5	0.3
3	1	1900	0.5	0.4
4	1	1500	0.7	0.2
5	1	1700	0.7	0.3
6	1	1900	0.7	0.4
7	1	1500	0.9	0.3
8	1	1700	0.9	0.4
9	1	1900	0.9	0.2
10	2	1500	0.5	0.4
11	2	1700	0.5	0.2
12	2	1900	0.5	0.3
13	2	1500	0.7	0.3
14	2	1700	0.7	0.4
15	2	1900	0.7	0.2
16	2	1500	0.9	0.4
17	2	1700	0.9	0.2
18	2	1900	0.9	0.3

Table 8 : S-N ratio analysis for MRR

Material	Feed	Speed	DOC	MRR	SNRA1
1	0.5	1500	0.2	2827.31	69.02747
1	0.5	1700	0.3	2086.25	66.38733
1	0.5	1900	0.4	2308.5	67.2666
1	0.7	1500	0.2	1787.63	65.04555
1	0.7	1700	0.3	2972.5	69.46244
1	0.7	1900	0.4	3762	71.50838
1	0.9	1500	0.3	2853.31	69.10698
1	0.9	1700	0.4	2224.5	66.94465
1	0.9	1900	0.2	1669.63	64.4524
2	0.5	1500	0.4	2816.31	68.99361
2	0.5	1700	0.2	4551	73.16214
2	0.5	1900	0.3	3360.13	70.52712
2	0.7	1500	0.3	3238.4	70.20661
2	0.7	1700	0.4	1384	62.82272
2	0.7	1900	0.2	3867	71.74748
2	0.9	1500	0.4	3337	70.46712
2	0.9	1700	0.2	2821.31	69.00902
2	0.9	1900	0.3	3105.7	69.84319

2.7 Raw Data Analysis for CNC Turning Operation

In this section mean of MRR to discuss the results for all process parameters, after that interaction plots are discussed to show the effect of various parameters among each other.

S/N Ration Analysis for MRR

Signal to noise ratio analysis is performed for material removal rate using option "larger is better" and the results are present in table 8 for the same. As seen in table 8, the S/N ratio is more useful then original data of material removal rate (MRR).

3. RESULTS & DISCUSSIONS

In previous chapter the experimentation through L18 ANOVA was conducted and output response material removal rate has been determined, here the experimental data have been examined and machining parameters are optimized through Taguchi technique.

S/N ratio based analysis for MRR is present in table 9 respectively. As seen in table 9, the best ranked factor is work piece material where as least ranked factor is feed rate.

As seen in figure 3 the high profile for S/N ratio is show for material where as low profile is show for feed rate. These diagram are used for finding the optimal solution for selective responses.

3.1 REGRESSION MODEL

The regression model to predict the theoretical material removal rate has derived from the experimental data by using MINITAB 17 software, the equation given below and also from the analysis the residual plot were drawn.

Table 9: Rank Identification for MRR (Larger is better) SN Ratio

Level	material	Feed	Speed	DOC
1	67.69	69.23	68.81	68.74
2	69.64	68.47	67.96	69.26
3		68.3	69.22	68
Delta	1.95	0.92	1.26	1.26
Rank	**1**	**4**	**2**	**3**

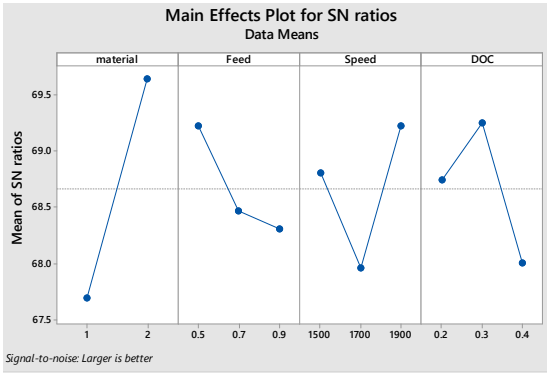

Figure 3 : S-N ratio analysis for MRR

Table 10 : ANOVA analysis for MRR for Linear model equation

Source	DF	Seq SS	Contribution	Adj SS	Adj MS	F-Value	P-Value	Remarks
Material	1	1992820	17.44%	1992820	1992820	2.96	0.109	**significant**
Feed	1	313003	2.74%	313003	313003	0.46	0.507	**insignificant**
Speed	1	122614	1.07%	122614	122614	0.18	0.677	**insignificant**
DOC	1	238451	2.09%	238451	238451	0.35	0.562	**insignificant**
Error	13	8756562	76.65%	8756562	673582			
Total	17	11423449	100.00%					

MRR = 45617 + 8944 material - 11070 Feed - 58.3 Speed + 29209 DOC - 1136 Feed*Feed+ 0.0183 Speed*Speed - 29213 DOC*DOC - 421 material*Feed - 2.30 material*Speed- 13909 material*DOC + 2.05 Feed*Speed + 29317 Feed*DOC - 8.1 Speed*DOC

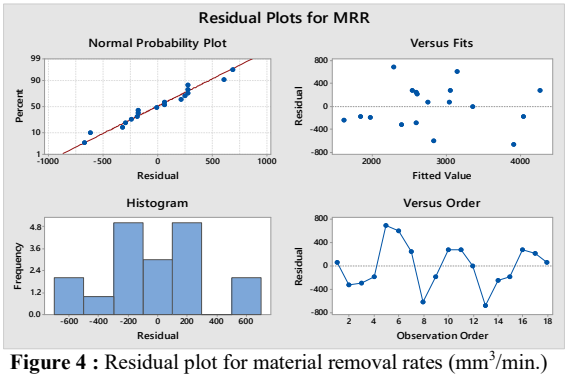

Figure 4 : Residual plot for material removal rates (mm^3/min.)

3.2 CONCLUSION

The CNC turning investigation on material removal rate has been carried out for EN 31 and mild steel, this research work the effect feed rate, depth of cut and rotational speed on response have been studied under L18 Taguchi's orthogonal array and significance of process parameters are analyzed via ANOVA. The following important conclusions drawn from this study:

- The material removal rate increases with increases in feed rate, MRR, depth of cut and spindle speed is high at dry machining condition.
- Depth of cut and spindle speed has significant effect on MRR.
- Feed rate has insignificant effect of material removal rate.
- The predicted optimal setting parameters for MRR is A2- B3-C3-D-2 (0.5 mm/rev-0.3mm-1900rpm).

4. SCOPE FOR FUTURE WORK

- The experiments can be done with different orthogonal array experiments like L16, L27 etc.
- The CNC turning optimization can be carried out by taking tool wear into account.
- The multi objective optimization can be performed with grey relation analysis/ ANOM/Fuzzy logic/ANN.
- The Ansys Modelling can be done.
- The surface integrity study and micro structure analysis can be done through scanning electron microscopy.

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