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Optimization of Material Removal Rate in CNC Turning of Mild Steel 1018 using Taguchi method

Arvind Kumar[1]
[1]Ganpati Institute of Technology and Management, Bilaspur, Yamunanagar
Email: Arvind.kumar4u@yahoo.com

Abstract- Engineering materials are presently in use at a very vast range in today's industries. As Mild steel 1018 has a wide variety of applications in construction of pipelines, products, construction as structural steel, car manufacturing industries and other major industries. The machining of these types of materials requires very important consideration. There are a number of parameters like cutting speed, feed and depth of cut etc. which must be given consideration during the machining of this alloy. So it becomes necessary to find out the ways by which it can be machined easily and economically. For the present work the parameter to be optimised selected is material removal rate that is optimised by using selected combination of machining parameters by using taguchi orthogonal array.

1. INTRODUCTION

In present industrialization world in engineering applications a number of materials are in use Low carbon steel is one of among all the materials, also known as mild steel, containing 0.05 % to 0.26 % of carbon (e.g. AISI 1018 steel). They are cheap, but engineering applications are restricted to non-critical components and general panelling and fabrication work. Consequently, there are usually no problems associated with heat affected zones in welding process.

The surface machining properties can be enhanced by carburizing and then heat treating the carbon-rich surface. Therefore the present work is focused on finding the optimal parameters combination of cutting speed, feed and depth of cut for maximizing the rate of material removal during machining.

2. EXPERIMENTAL SETUP

2.1. WORKPIECE PREPARATION

The specification of workpiece used is Mild Steel 1018 having diameter 25 mm and of 415 length.

Figure 1: Workpieces

2.2 CHEMICAL COMPOSITION

The chemical composition of the selected material is as:

Table 1: Chemical composition

Element	Percentage
Iron, Fe	98.81 - 99.26%
Carbon, C	0.26%
Manganese, Mn	0.6 - 0.9%
Phosphorus (P)	0.04% max
Sulfur (S)	0.05% max

2.3 CNC MACHINE

CNC lathe machines today is used at very huge range over a vast applications in industries. Better machines are with broad bearing surfaces (slides or ways) for stability, and manufactured with great precision helps to ensure the components to meet the required tolerances and repeatability. For present work the machine used is HMT Stallion 100 HS.

Figure 2: CNC Machine

Tool Material

The coated carbide tool single point cutting tool is used of make SANDVIK. This selection of tool bit depends on many factors like workpiece hardness and tool life required and the operating conditions etc.

2.4 SELECTION OF CUTTING PARAMETERS

The selection of the cutting parameters and design array needs very much attention in any experimental research work. The cutting parameters selected are as:

1. Cutting speed
2. Feed
3. Depth of cut

2.5 SELECTION OF OPTIMIZATION PARAMETER

The parameter selected to be optimized is Material Removal Rate (MRR).

2.6 ROUGHNESS MEASUREMENT

Material Removal Rate (MRR) is calculated from the multiplication of cutting speed, feed rate and depth of cut by using the relation:

$MRR= W_b-W_a/qt$

Where, W_b-Weight before machining (Kg)

W_a-Weight after machining (Kg)

q-Density of brass (Kg/mm^3)

t-Machining time (seconds)

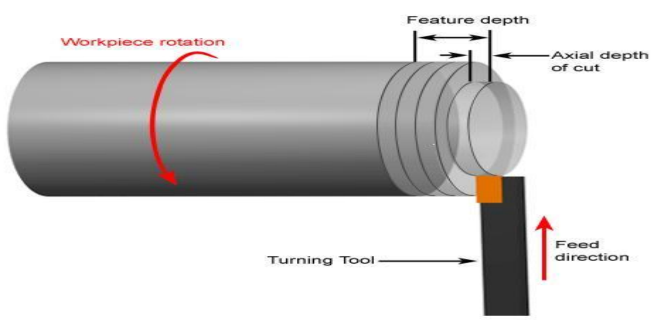

Figure 3: Metal Removal Process

3. DESIGN OF EXPERIMENT

The following are the most common DOE techniques given below:

1) One Factor Designs

2) Factorial Designs
3) Taguchi's Orthogonal Arrays
4) Response Surface Method Designs
5) Mixture Designs

From all these the selected one is Taguchi's orthogonal arrays.

3.1 TAGUCHI'S ORTHOGONAL ARRAYS

Taguchi's orthogonal arrays are highly fractional designs, used to estimate main effects using only few experimental runs. Designs are also available to investigate main effects for certain mixed level experiments where the factors included do not have the same number of levels. For example, a four-level full factorial design with five factors requires 1024 runs while the Taguchi orthogonal array reduces the required number of runs to 16 only.

4. RESULTS

4.1 OPTIMIZATION OF MRR USING TAGUCHI METHOD

Table 2: MRR mean and S/N ratio

S. No	CS (mm/min)	FR (mm/rev)	DOC (mm)	MRR(mm^3/min)	S/N Ratio(dB)
1	60	0.25	0.2	0.045	-26.93
2	60	0.25	0.3	0.042	-27.53
3	60	0.25	0.4	0.046	-26.74
4	60	0.35	0.2	0.047	-26.55
5	60	0.35	0.3	0.048	-26.37
6	60	0.35	0.4	0.046	-26.74
7	60	0.45	0.2	0.045	-26.93
8	60	0.45	0.3	0.043	-27.33
9	60	0.45	0.4	0.044	-27.13
10	80	0.25	0.2	0.050	-26.02
11	80	0.25	0.3	0.051	-25.84
12	80	0.25	0.4	0.052	-25.67
13	80	0.35	0.2	0.049	-26.19
14	80	0.35	0.3	0.050	-26.02
15	80	0.35	0.4	0.048	-26.37
16	80	0.45	0.2	0.051	-25.84
17	80	0.45	0.3	0.052	-25.67
18	80	0.45	0.4	0.050	-26.02
19	100	0.25	0.2	0.048	-26.37
20	100	0.25	0.3	0.051	-25.84
21	100	0.25	0.4	0.050	-26.02
22	100	0.35	0.2	0.048	-26.37
23	100	0.35	0.3	0.051	-25.84
24	100	0.35	0.4	0.047	-26.55
25	100	0.45	0.2	0.050	-26.02
26	100	0.45	0.3	0.049	-26.19
27	100	0.45	0.4	0.051	-25.84

The observed data for MRR has been analysed using the Taguchi optimization method and Analysis of Variance with the help of MINITAB 16 software. The Signal to noise ratio has been calculated based on Taguchi's larger the better approach as it aims to maximise the material removal rate by using the following relation:

$\eta = -10\log 1/n \sum_{i=1}^{n} 1/y_i^2$

Table 3: ANOVA of S/N ratios of MRR

Variable Factors	DF	SS	V	F	P	% Cont.
Cutting speed	2	424.15	212.075	26.50	0.74	78.424***
Feed rate	2	11.12	5.56	0.695	0.11	2.056
Cutting speed*Feed	4	41.66	10.415	1.301	2.18	7.702**
Depth of cut	2	18.83	9.415	1.176	0.417	3.481
Cutting speed*DOC	4	6.86	1.715	0.214	1.45	1.268
Feed rate*DOC	4	12.71	3.177	0.397	0.851	2.35
Error	8	25.54	3.192			4.722*
Total	26	540.84				100

Table 4: Response Table of S/N ratios of MRR

Level	Cutting Speed (A)	Feed Rate (B)	Depth of cut (C)
1	0.0452	0.0486	0.0480
2	0.0502	0.0485	0.0488
3	0.0498	0.0486	0.0482
Rank	4	1	3

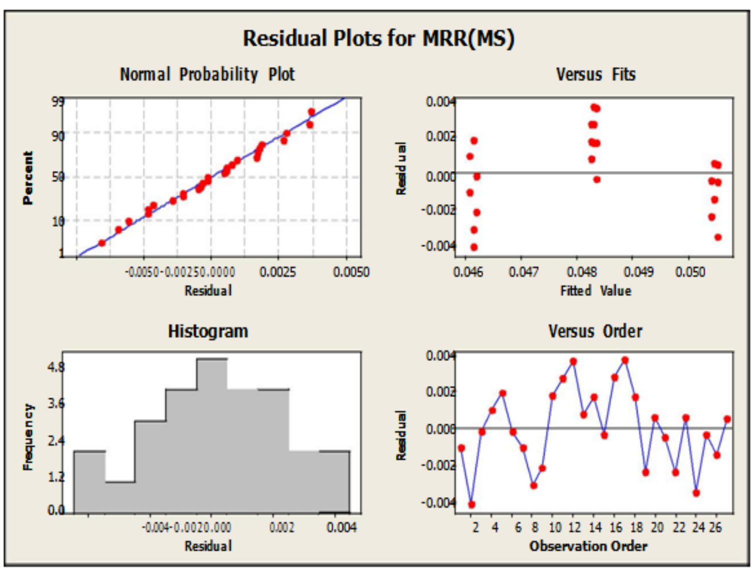

Figure 4: Residual Plot

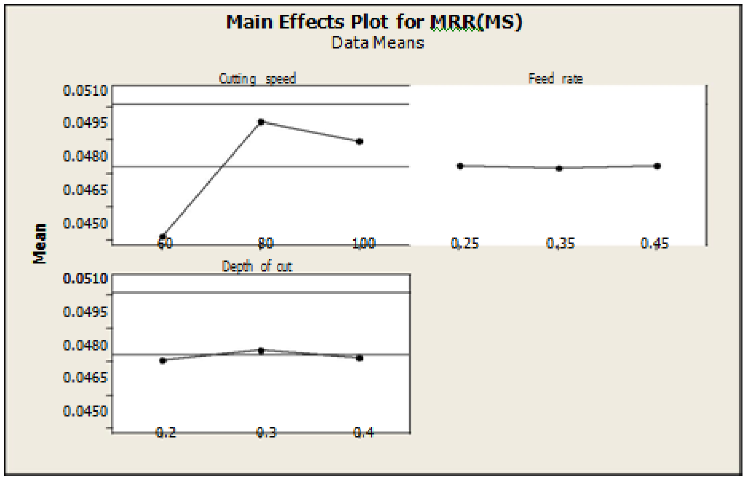

Figure 5: Main Effect Plot for S/N ratio

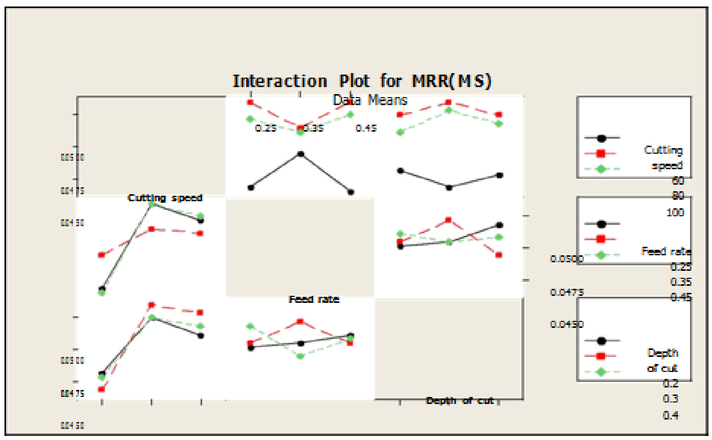

Figure 6: Interaction Plot for S/N Ratio

4.2 DETERMINATION OF OPTIMUM CONDITION

Both the response and S/N ratio are used to derive the optimum conditions. Since for quality characteristic, MRR larger the better approach is desirable, the largest response is the ideal level for a parameter. The S/N ratio is always highest at the optimum condition.

4.3 Predictive equation and verification

The predicted value of MRR at the optimum levels is calculated by using the relation :

$$\eta = \eta_m + \sum_{i=1}^{o}(\eta_{im} - \eta_m)$$

Where η the total mean S/N ratio is η_m, η_{im} is the mean S/N ratio at optimal level and o is the number of main design parameters that affect the quality characteristic.

Applying this relation predicted value of SRR at the optimum conditions is obtained as:

$$\eta = 0.042 + [(0.046 - 0.042) + (0.045 - 0.042) + (0.048 - 0.042)]$$

$$\eta = 0.055 mm^3/min$$

The robustness of this parameter optimization is verified experimentally. This requires the confirmation run at the predicted optimum conditions. The experiment is conducted at the predicted optimum conditions and the average of the response is 0.055. The error in the predicted and experimental value is only 0.6%, so good agreement between the actual and the predicted results is observed. Since the percentage error is less than 5%, it confirms excellent reproducibility of the results. The results show that using the optimal parameter setting ($A_1B_3C_2$) a higher material removal rate is achieved.

Table 5: Comparison of Results

Variables	Optimal values of responses	Optimal setting Level	Predicted optimal value	Optimal value Of MRR	Experime Ntal Values
Cutting speed(A) Feed rate(B) Depth of cut(C)	60mm/min 0.45mm/revs 0.30mm	A1 B2 C2	0.055	0.052 $<\eta_{MRR}>$ 0.055	0.052

5. CONCLUSIONS

This study demonstrates that, when feasible process parameters are selected, mild steel (1018) could be efficiently turned using coated carbide tool. The coated carbide tool with better mechanical and thermal properties is proved to be a better choice for turning mild steel. The feed rate shows an impetus effect on material removal rate. The analysis of material removal rate further confirmed such results. The research into the machining of mild steel is continuing in several fronts, including turning and burnishing processes.

An experimental approach to the evaluation of material removal rate and surface roughness in turning medium brass alloy by coated carbide using Taguchi method is presented in this study.

1.Effect of workpiece material: It can be noted that mild steel (1018), is adifficult to machine with a hardness rate (107.5 - 172.5 HV), tensile strength (345 - 580 MPa), and density (7861.093 kg/m^3).In this condition, when the process conditions are right, is easier to turn.

2.Effect of tool material: The coated carbide turning tool has a high elasticmodulus. This leads to the more efficient turning of work material as compared to the tool material.

3. Effect of cutting speed, feed rate and depth of cut: Surface roughness increases when feed rate increases, however cutting speed also the influencing parameter followed by depth of cut.

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