Optimization of Surface Roughness in CNC Turning of Mild Steel (1018) using Taguchi method

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Abstract

Mild steel 1018 has a wide variety of applications in electrical devices,, construction of pipelines, products, construction as structural steel, car manufacturing industry, railway parts and other major industries. 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 surface roughness that is optimised by using selected combination of machining parameters by using taguchi orthogonal design.

1. Introduction

For engineering applications a no of materials are in use Low carbon steel is one of among all the materials, also known as mild steel, containig 0.05 % to 0.26 % of carbon (e.g. AISI 1018, AISI 1020 steel). They cannot be modified by heat treatment. They are cheap, but engineering applications are restricted to non-critical components and general panelling and fabrication work. These steels cannot be effectively heat treated. Consequently, there are usually no problems associated with heat affected zones in welding process. The surface 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 lower surface roughness.

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

4 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.

2.5 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 Surface Roughness.

2.6 Roughness measurement

Roughness is measured using a portable stylus-type surface roughness tester, Surftest SJ-301 (Mitutoyo, Japan). The measurement results are displayed digitally and graphically on the touch panel and output to the built in printer. The Mitutoyo instrument (Surftest SJ-301) is a portable, self-contained instrument for the measurement of surface texture. It is equipped with a diamond stylus having a tip radius 5 μm. The measuring stroke always starts from the extreme outward position. At the end of the measurement the pickup returns to the position ready for the next

measurement.

Figure 3: Surface Roughness Tester

Two readings are taken first then average of these two values are taken for optimization.

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 surface roughness using Taguchi method
The observed data for surface roughness (R_a) 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 smaller the better approach as it aims to minimise the surface roughness by using the following relation:

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

Table 2: Surface Roughness mean and S/N ratio

S. No	CS (mm/min)	FR (mm/rev)	DOC (mm)	SR (µm)	S/N Ratio(dB)
1	60	0.25	0.2	5.60	-14.96
2	60	0.25	0.3	7.10	-17.02
3	60	0.25	0.4	7.40	-17.38
4	60	0.35	0.2	7.10	-17.02
5	60	0.35	0.3	6.03	-15.60
6	60	0.35	0.4	6.98	-16.87
7	60	0.45	0.2	4.85	-13.71
8	60	0.45	0.3	5.55	-14.88
9	60	0.45	0.4	6.31	-16.00
10	80	0.25	0.2	4.23	-12.52
11	80	0.25	0.3	4.44	-12.94
12	80	0.25	0.4	5.14	-14.21
13	80	0.35	0.2	3.84	-11.68
14	80	0.35	0.3	5.57	-14.91
15	80	0.35	0.4	5.73	-15.16
16	80	0.45	0.2	4.06	-12.17
17	80	0.45	0.3	4.85	-13.71
18	80	0.45	0.4	6.28	-15.95
19	100	0.25	0.2	4.12	-12.29
20	100	0.25	0.3	3.57	-11.05
21	100	0.25	0.4	3.30	-10.37
22	100	0.35	0.2	3.41	-10.65
23	100	0.35	0.3	3.12	-09.88
24	100	0.35	0.4	3.42	-10.68
25	100	0.45	0.2	2.63	-08.39
26	100	0.45	0.3	4.33	-12.72
27	100	0.45	0.4	4.10	-12.25

Table 3: ANOVA of S/N ratios of surface roughness

Variable Factors	DF	SS	V	F	P	% Cont.
Cutting speed	2	518.63	259.315	32.41	0	21.52***
Feed rate	2	143.82	71.91	8.98	0.002	5.968
Cutting speed*Feed	4	477.36	119.34	14.91	0.009	19.810**
Depth of cut	2	312.54	156.27	19.53	1.07	12.978
Cutting speed*DOC	4	189.75	47.437	5.929	0.754	7.874
Feed rate*DOC	4	417.87	104.467	13.05	0.004	17.347
Error	8	349.72	43.715			14.513*
Total	26	2409.69				100

Table 4: Response Table of S/N ratios of surface roughness

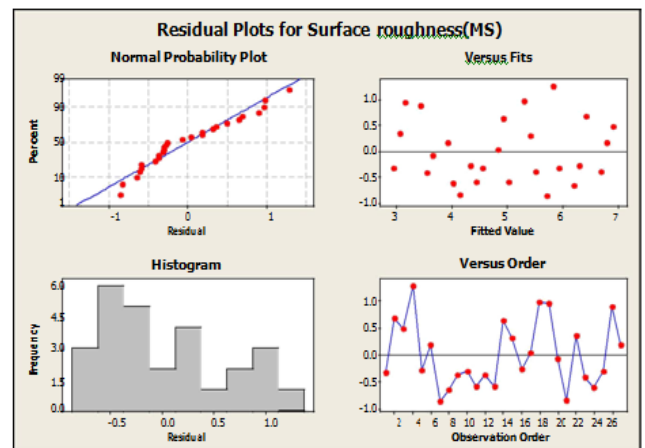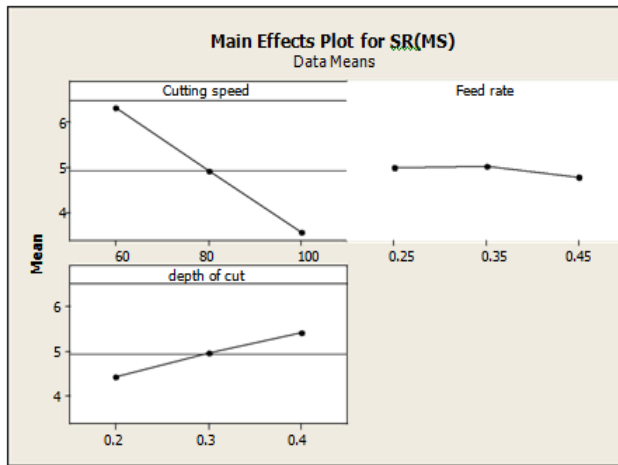| Level	Cutting Speed (A)	Feed Rate (B)	Depth of cut (C)
1	6.92	4.99	4.56
2	4.98	5.0	4.96
3	3.21	4.91	5.49
Rank	4	1	3

Figure 4: Residual Plot
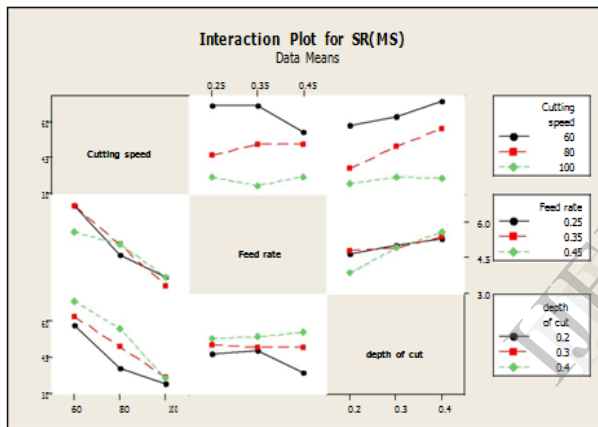
Figure 5: Main Effect Plot for S/N ratio

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, surface roughness smaller the better approach is desirable, the smallest response is the ideal level for a parameter. The S/N ratio is always highest at the optimum condition. The graph of Figure (b) is used to determine the optimum process parameters combination. The optimum combination is therefore $A_3B_3C_1$.

4.3 Predictive equation and verification

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

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

Where n the total mean S/N ratio is $n.\dot{i}\cdots\bar{m}$ 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:

$$\eta_{Ra} = 4.85 + [(5.57 - 4.85) + (5.55 - 4.85) + (5.14 - 4.85)]$$

$$\eta_{Ra} = 6.56\ \mu m$$

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 6.56 μm. The error in the predicted and experimental value is only 3.2%, 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 $(A_3B_3C_1)$ a smaller surface roughness is achieved.

Table 5: Comparison of Results

Variables	Optimal values of responses	Optimal setting Level	Predicted optimal value	Optimal value Of SR()	Experimental Values
Cutting speed(A)	100 mm/min	A_3 B_3 C_1	6.56	6.23 $<\eta_{SR}>$ 6.56	6.23
Feed rate(B)	0.45 mm/revs				
Depth of cut(C)	0.20 mm				

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 surface roughness. The analysis of surface roughness 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 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 a difficult 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 elastic modulus. 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.

6. References

[1] M.Y. Noordin, V.C. Venkatesh, "Application of response surface methodology in describing the performance of coated carbide tools when turning AISI 1045 steel", Journal of Materials Processing Technology 145 (2004) 46–58, Received 19 June 2002; received in revised form 28 June 2003; accepted 2 July 2003.

[2] Aman Aggarwal, Hari Singh, "Optimization of machining techniques- A retrospective and literature review", S̄adhan̄a Vol. 30, Part 6, December 2005, pp. 699–711.

[3] Guey-Jiuh Tzou, Ding-Yeng Chen, "Application of Taguchi method in the optimization of cutting parameters for turning operation", 2006.09.

[4] S. Thamizhmanii, B. Bin Omar, "Surface roughness analysis on hard martensitic stainless steel by turning", Journal of Achievements in Materials and Manufacturing Engineering, Volume 26 Issue 2 February 2008.

[5] Aman Aggarwal, Hari Singh, "Optimizing feed and radial forces in CNC machining of P-20 tool steel through Taguchi's parameter design approach", Indian Journal of Engineering & Materials Sciences, Vol. 16, February 2009, pp.23-32

[6] N. Muthukrishnana, J. Paulo Davimb, "Optimization of machining parameters of Al/SiC-MMC with ANOVA and ANN analysis", journal of materials processing technology 2 0 9 (2 0 0 9) 225–232.

[7] Ali Riza Motorcu, "The optimization of machining parameters using the Taguchi method for surface roughness of AISI 8660 hardened alloy steel", Journal of Mechanical Engineering 56(2010)6, 391-401,UDC 669.14:621.7.015: 621.9.02,.

[8] D. Philip Selvaraji, P. Chandramohan, "Optimization of surface roughness of AISI 304 austenitic stainless steel in dry turning operation using Taguchi design method" Journal of Engineering Science and Technology. Vol. 5, No. 3 (2010) 293 – 301.

[9] Saurav Datta, Siba Sankar Mahapatra, "Simultaneous optimization of correlated multiple surface quality characteristics of mild steel turned product ", Intelligent Information Management, 2010, 2, 26-39, Published Online January 2010.

[10] PD Kamble, AC Waghmare, "Optimization of Turning Operation – A Review" VSRD International Journal of Mechanical, Auto. & Prod. Engg. Vol. 1 (3), 2011.