ISSN: 0974-5823 Vol. 7 (Special Issue, Jan.-Feb. 2022)

International Journal of Mechanical Engineering

OPTIMIZATION OF SURFACE ROUGHNESS IN TURNING MARTENSITIC STEEL BY USING TAGUCHI METHOD

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ABSTRACT

The surface quality of the machined parts is one of the most important product quality characteristics and one of the most frequent customer requirements. In this study the Taguchi robust parameter design for modelling and optimization of surface roughness in dry single-point turning of hard martensitic stainless steel using Ti16Zr coated carbide inserts is presented. Three cutting parameters, the RPM speed (400, 450, 500 rpm), the feed rate (0.25, 0.3, 0.35 mm/rev), and the depth of cut (0.25, 0.3, .35 mm), are used in the experiment. Each of the other parameters are taken as constant. The average surface roughness (Ra) was chosen as a measure of surface quality. The experiment was designed and carried out on the basis of standard L_9 Taguchi orthogonal array. The data set from the experiment was employed for conducting the optimization procedures, according to the principles of the Taguchi method. The results of calculations were in good agreement with the experimental data. A certain discrepancy between the experimental results and calculations could be interpreted as the presence of measurement errors, many irregularities and deficiencies in the turning process, as well as environmental effects. The results presented in this work confirm the effectiveness of Taguchi's technique in optimization of cutting processes.

Keywords: turning process, surface roughness, Taguchi method, regression analysis, ANOVA analysis.

INTRODUCTION

Turning is one of the most fundamental and applied metal cutting operations in a real manufacturing environment among different cutting processes. One of the most important product quality characteristics is the surface roughness of the machined components. This function refers to the deviation from 3rd to 6th order nominal surface.

- The real surface profile is the overlay of shape defect, onset and ruggedness. International norms describe the order of deviation. Surface roughness significantly affects the working of mechanical components such as wear resistance, tiredness, lubricant delivery, heat generation and transmission, corrosion resistance, etc.

- In the absence of irregularity and defects in the cutting process, as well as environmental impact, the optimal surface quality will not be obtained when turning. Different criteria for measuring surface roughness are used. The average surface ruggedness (Ra) was selected for surface finish during turning operation in the current report.

- HCHCr-High carbon high chromium steel is one of these materials. For the machining of High carbon high chromium steels, the cutting tool materials must be harder than the work piece materials. These types of materials can be machined with carbide tools [1].

- Among the cutting parameters affecting machining variables for steel, speed has maximum effect & depth of cut has minimum effect. Tool tip temperature increases with increase in cutting speed. At high speeds, surface finish is least affected. Surface finish deteriorates at high feed rates; hence to obtain good surface finish, feed rate may be kept low. At low speeds cutting force are high & tendency of work material to form a built up edge is also stronger. At lower speeds, surface roughness increases with increasing feed but at higher speeds surface roughness is less dependent on feed [2]. The Taguchi parameter design method is an efficient experimental method in which a response variable can be optimized, given various control and noise factors, and using fewer experimental runs than a factorial design [3].

- Hence, it is of great importance to exactly quantify the relationship between surface roughness and cutting conditions. The materials having high-tensile strength and resistance to wear and impact, which are frequently used for drawing dies, blanking dies, forming dies, bushings, gauges, etc., are generally difficult to machine[5]. This paper demonstrates the application of the Taguchi method for identifying the optimal cutting parameters for surface roughness in dry turning of high carbon high chromium steel.

2. LITERATURE REVIEW

- Suresh Dhiman, et al [2008] studied effect of cutting parameters (feed, speed, depth of cut) of AISI 1018 steel on various factors (tool tip temperature, surface roughness, and cutting forces) that account for machining costs. A cylindrical bar of AISI 1018 steel (length 125 mm, diameter 25 mm) was used to carry out experiments on lathe .

- HSS single point cutting tool without using any coolant. Among the cutting parameters affecting machining variables for AISI 1018 steel, speed has maximum effect & depth of cut has minimum effect. Tool tip temperature increases with increase in cutting speed. At high speeds, surface finish is least affected. Surface finish deteriorates at high feed rates; hence to obtain good surface finish, feed rate may be kept low. Annealing & normalising AISI 1018 steel would improve machinability by coarsening pearlite. At low speeds cutting force are high & tendency of work material to form a built up edge is also stronger. At lower speeds, surface roughness increases with increasing feed but at higher speeds surface roughness is less dependent on feed [2].

- E. Daniel Kirby, et al [2006] presented an application of the Taguchi parameter design method to optimizing the surface finish in a turning operation. The Taguchi parameter design method is an efficient experimental method in which a response variable can be optimized, given various control and noise factors, and using fewer experimental runs than a factorial design. The control parameters for this operation included: spindle speed, feed rate, depth of cut, and tool nose radius. Noise factors included varying room temperature, as well as the use of more than one insert of the same specification, which introduced tool dimension variability. A total of 36 experimental runs were conducted using an orthogonal array, and the ideal combination of control factor levels was determined for the optimal surface roughness and signal to noise ratio. A confirmation run was used to verify the results, which indicated that this method was both efficient and effective in determining the best turning parameters for the optimal surface roughness [3].

- Author held experimental analysis of martensitic stainless steel by uncoated and coated carbide tool inserts. The results were founded that coated carbide tool inserts are more efficient then uncoated carbide tool inserts so final set of experiments were carried out by stastical method Taghuchi L27.Major output response was surface roughness[4]. In this research work author identified different methods of lean six sigma by applying mathematical model ANN and implement it in various manufacturing industries[5]. It is the most commonly used surface roughness standard parameter. Two sharp and sometimes conflicting specifications exist in a machining phase. Firstly, high surface quality and, secondly, a high rate of production. Extremely high surface quality can lead to higher costs of production and time consumption. Therefore, machine tool operators would not force to their limits the machine tool and/or cutting tool, but would instead use less dangerous process factors, which neither guarantee the desired surface quality nor achieve maximum output or low cost of production [6].

3. EXPERIMENTAL DETAILS AND PROCEDURE:

This experiment was conducted using the hardware listed in Table 1 on CNC lathe machine as shown in the figure 1.

Table 1: Hardware list

Sr. No.	Item	Specifications
1	CNC lathe	Lakshmi Machine Works (LMW), Model- SMARTURN Spindle: Max. Speed- 4500 rpm; Max. Power Rating – 7.5/5.5 KW; Spindle Nose- Flat (Dia. 140); Spindle Bore Dia.-53 mm Travels & Feed rates: X-axis- 105 mm; Z-axis- 320 mm; Rapids on X-axis- 20 m/min; Rapids on Z axis- 20 m/min General: Weight- 2300 kg; Power requirement- 15 KVA ; 3- phase : 415 V; wire-4; frequency- 50 Hz
2	Surface roughness measurement device	Model: Surf test SJ201 P (Mitutoyo) Cut-off Values (lc): 0.8mm; Evaluation Length(es): 12.5mm; Drive speed:Measuring:0.25mm/s,0.5mm/s),Returning:0.8mm/s; Power Supply:100-240V AC, 50-60Hz,Via AC adapter/built- in rechargeable battery; Roughness parameter: Ra in µm; Stylus tip radius: 5 µm; Measuring force: 4 mN.
3	Cutting tool inserts	ISO Grade-TNMG 160408 MC;Grade:TT5100;Composition:TiCN,Al2O3,TiN; Coat:MTCVD

The cutting parameters (design factors) considered in the present paper were RPM speed (N), feed rate (f), and depth of cut (t). Other parameters were kept constant for the scope of this research. The average surface roughness (Ra) was chosen as the target function (response, output). Since it was obvious that the effects of factors on the selected function were nonlinear, the experiment was set up with factors at three levels (Table 2). The factor ranges were chosen with different criteria for each factor, in order to use the widest possible ranges of values. Also, the possibility of mechanical system and manufacturer's recommendation were taken into account.

Figure 1: CNC Lathe

Table 2: Process variables and their limits

SR.NO	PARAMETERS	LEVEL 1	LEVEL 2	LEVEL 3
1	Cutting speed (RPM)	400	450	500
2	Feed (mm/rev)	0.15	0.2	0.25
3	Depth of cut(mm)	.25	.3	.35

Table 3: Response parameter with signal to noise ratio

Sr.no	Cutting speed	Feed	Depth of cut	RA	SNRA1
1	400	0.15	0.25	0.435	7.230215
2	400	0.2	0.3	0.512	5.814601
3	400	0.25	0.35	0.246	12.1813
4	450	0.15	0.3	0.949	0.454676
5	450	0.2	0.35	1.441	-3.17328
6	450	0.25	0.25	0.612	4.264972
7	500	0.15	0.35	0.564	4.974418
8	500	0.2	0.25	0.487	6.249421
9	500	0.25	0.3	0.762	2.360901

Based on the selected factors and factor levels, a design matrix was constructed (Table 3) in accordance with the standard L9 Taguchi orthogonal array (OA). The three levels of each factor were denoted by -1, 0 and 1. This design provided uniform distribution of experimental points within the selected experimental hyper-space and the experiment with high resolution. Experimental input parameters were selected according to shown in table 3 by Taghuchi orthogonal array method. According to set of experiments results were obtained , analysis of each output response was carried out by Minitab software. Signal to noise ratio shown that optimum parameter selection could be carried out. These all experiments were performed on CNC 200MX machine. The dimensions of material was held 300 mm long and 25mm in diameter.

Table 4; Composition of work piece material

Elements	Weight Percentage
Carbon	0.16%
Silicon	.7%
Manganese	.75%
Nickel	1.97%
Chromium	15.5%
Phosphorus	0.021%
Sulphur	0.018%

TiCN,Al2O3,TiN. coated carbide inserts, type CNMG120408E, were used for turning. The average surface roughness (Ra) of machined workpieces was measured using Surf test SJ201 (Mitutoyo) profilometer (Figure 2). The form of inserts was the rhombic chip breaker (80^{o} point angle) geometry that was mounted on the PSBNR 2525M12 tool holder as shown in the Figure

3.3. The cutting angle = 0^0, side and back rake = -6º angle of input= 75º, angle of point = 90º, and radio of the nose = 0,8 mm are provided by the following geometry. The average surface roughness values shown in Table 3 are the arithmetical mean of three measurements.

4. RESULTS & DISCUSSIONS

From Table 3 which shows Experimental Data Related to Surface roughness Design of Experiment [DOE] using Taguchi's Analysis, Regression Analysis & ANOVA for Main effects plot has been done using MINITAB 16.1 application software. Results of the same with their respective graphs & interpretations are mentioned below in the sequential order.

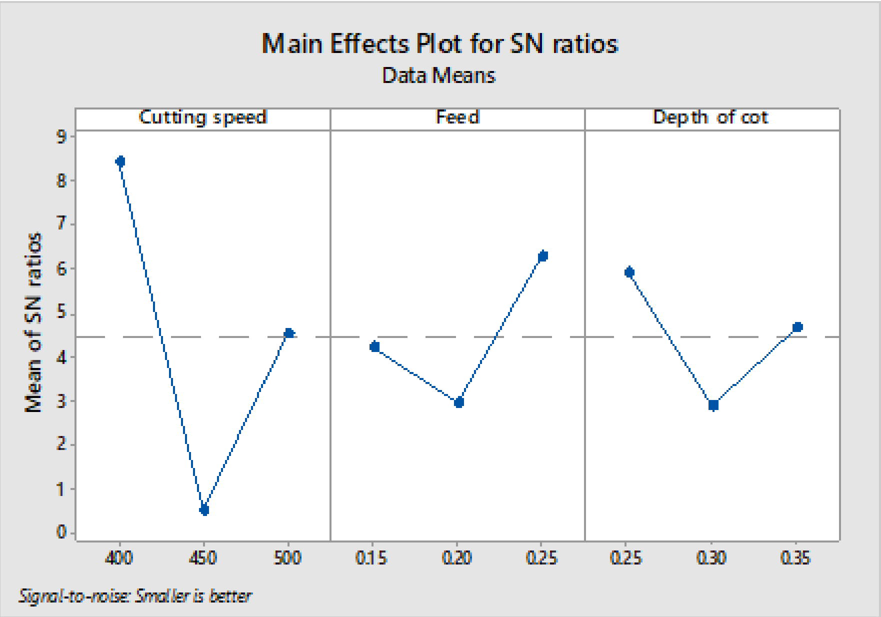
Taguchi Design

Taguchi Orthogonal Array Design L_9 (3**3) Factors: 3 Runs:9 Columns of L_9 (3**4) Taguchi Analysis: Ra in µm versus Speed in RPM, Feed in mm/rev, Depth of cut in mm

Level	Cutting speed	Feed	Depth of cut
1	8.4087	4.2198	5.9149
2	0.5155	2.9636	2.8767
3	4.5282	6.2691	4.6608
Delta	7.8932	3.3055	3.0381
Rank	1	2	3

Table 5: Response Table for Signal to Noise RatiosSmaller is better

The Response table for the surface roughness data show that: For the S/N ratios, RPM speed is ranked 1, depth of cut 3 & feed 2 which are justified using main effects plot for SN ratios as shown in the above graph 1. The rank of the parameter considering its contribution to minimize surface roughness (RA) is shown in the Table no.5. The lowest level of surface roughness were achieved at A2B2C2 levels of combination. Cutting speed is the most important factor and is ranked 1^{st} and feed is the 2^{nd}most important factor followed by depth of cut.



Graph 1:- Main Effects Plot for SN ratios [Ra]

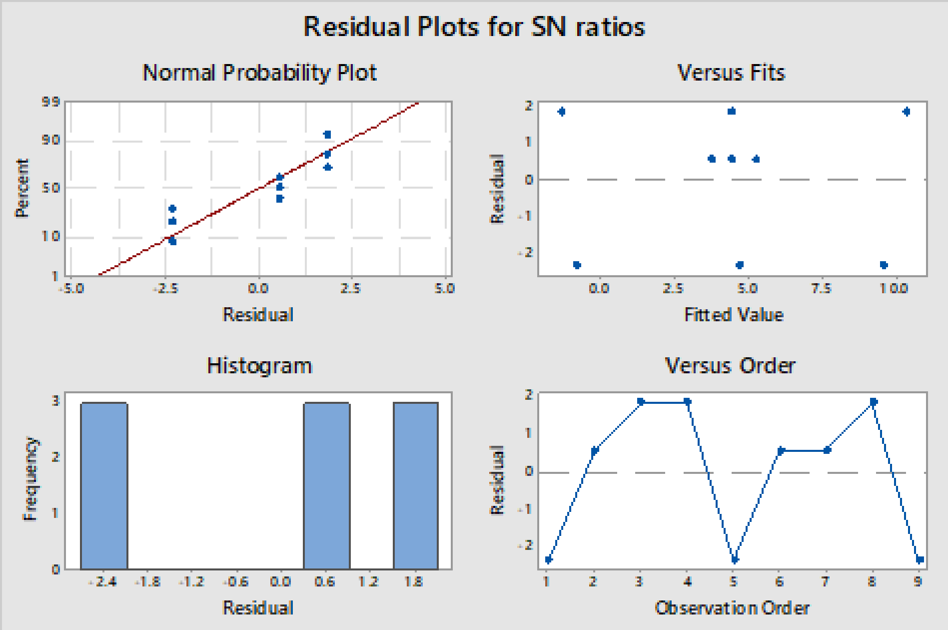
Regression Analysis

Regression Analysis: Ra in µm versus Speed in RPM, Feed in mm/rev, Depth of cut in mm

,

Table 6: Analysis of Variance for SN ratios

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Cutting speed	2	93.46	93.46	46.732	3.44	0.225
Feed	2	16.70	16.70	8.352	0.61	0.619
Depth of cot	2	13.99	13.99	6.993	0.51	0.660
Residual Error	2	27.19	27.19	13.595		
Total	8	151.34				



Graph 2 : Residual plots for RA

Above fig.5.3 shows different residuals plots for Ra. Which shows that optimum points of reading from 27 experiments are follow the residual line. Results of Ra was available within versus fit to model which suggest constant variance of residuals. Residuals are normally distributed as visible from the probability plot and histogram and they move around a constant mean, hence assumptions of regression model are met. Regression analysis of Ra shows that most dominant parameters are cutting speed and feed both. Optimal solution for surface roughness is obtained from set of output response.

Model Summary

S	R-Sq	R-Sq(adj)
3.6871	92.03%	98.14%

Chip Morophology for martensitic SS43100;

By machining coated tool inserts optimum cutting chip geometry was find out at cutting speed 450 r.p.m. At very low speed more friction was occure in between tool and work piece surface which shown that effect on surface finish. In below figures shows images of cutting chip at three set of experiments and b shows maximum continuos chips as compared to others a, c

CONCLUSION & FUTURE SCOPE

Among the cutting parameters affecting the surface roughness for Martensitic steel SS43100, speed has maximum effect & feed has minimum effect. At high speeds, surface finish is least affected. At low speeds surface roughness increases with increasing feed but at higher speeds surface roughness is less dependent on feed.

Also from results of ANOVA main effects plots it is clear that these results fully support the conclusions derived earlier.

Above images of cutting chips conclude that best solution for machining is at medium speed , feed and depth of cut. If increase cutting speed then forces of cutting were also increased which consumed more electrical power consumption.

For optimum solutions for surface roughness was find out by single objective method were cutting speed was 450r.p.m. , feed 0.20 mm/rev and depth of cut was 0.30 mm.

The future scope for the further development of this experimental investigation is recommended as follows:

1. The future work can be carried out by selecting machining environment like wet machining, lubrication plaied important role on machining of martensitic stainless steel.
2. Various kinds of other cutting tool materials can be used for the experimental investigation of turning operation on the same workpiece material.

ACKNOWLEDGMENT

I offer my most sincere humble thanks Mechanical Engineering Department, Government Engineering College, Bhavnagar. Not only for giving his valuable guidance, unflagging encouragement and inspiration, but also for them never-ending willingness to tender generous. It is with humble gratitude & sense of indebtedness.

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