Optimization of Cutting parameters for Surface roughness in CNC turning of P20 steel

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Abstract: The surface roughness is one of the most commonly used criteria to determine the quality of turned steel. The surface roughness of a turned surface is an important response parameter. The quality of product such as laptops, cell phones made by injection moulding greatly depends on finishing of the moulds. Surface roughness is one of the important factors for the materials used for making moulds and dies such as P20 steel. This paper optimize the cutting parameters such as feed rate, depth of cut and cutting speed for the turning process of AISI P20 steel (mould steel) for better surface finish. Taguchi's technique has been used to accomplish the objective of the experimental study. L-9 Orthogonal array, Signal to noise (S/N) have been used for conducting the experiments.

Key words: Optimization, Surface Roughness (Ra), Taguchi, Turning, P20 steel.

1. INTRODUCTION

Molds have specific geometries based on the profile of injected products, which corresponds to a great challenge in the manufacturing sector. The market for molds is becoming more demanding and competitive each passing day and this requires constant technological innovation of companies in that sector.

Manufacturers who are competing in the market want their product to be manufactured at less cost. The setup for machining a component should be effective which takes less time and effort. Optimization of cutting parameters such as cutting speed feed rate and depth of cut gives better surface finish, takes minimum time and produce less tool wear.

High speed machining technologies and use of modern machine tools enables the improvement of surface roughness by accurate displacement of tool and good surface finish of the machined surface. High speed machining alone however is not enough to optimize the quality in the manufacturing sector because of the complexities involved in its precise control which make it difficult to employ by the manufacturers. P20 steel which is used in molds has to be machined in pre hardened condition as no heat treatment can be done after machining as the accuracy and quality of surface finish is very important criteria in molds. Thus the correct selection of cutting parameters generates optimum conditions during the machining of molds, and becomes the main exigency of manufacturing industry.

2. LITERATURE REVIEW

J.S.Dureja, Rupinder Singh et al. [1] applied Taguchi L9 orthogonal array for experimental design. S/N ratio and ANNOVA analysis were performed on D3 steel to identify significant parameters influencing tool wear and surface roughness. Results signify the cutting speed to be the most significant factor influencing flank wear. **Dr. C. J. Rao et al.** [2] studied and discussed the influence of cutting parameters on cutting force and surface finish in turning operations. The authors used work material of 1050 steel (hardness of 484 HV) with tool made of ceramic with an Al203 + Tic matrix (KY1615). **R Ramanujan and K venketesan** [3] evaluated dry turning of inconel718 using carbide inserts using Taguchi's L9 array. Feed rate was found to be the most significant parameter for surface roughness. **A Mahamani et al.** [4] used Taguchi method to optimize the machining parameters. The influence of process parameters on cutting force and surface roughness during turning of AA2219-TiB2/ZrB2 In situ metal matrix composites was done. L27 orthogonal layout was used for experimentation. The response graph and analysis of variance shows that feed rate has strongest effect on surface roughness and cutting force. **Shreemoy Kumar Nayak et al.** [5] conducted multi objective optimization of machining parameters in dry turning of AISI 304 Austenite stainless steel. Three imp characteristics MRR, cutting force and surface roughness were measured. **Libor Beraneka et al** [6] carried out Design of experiment to optimize the turning parameters like cutting speed, depth of cut and feed of duplex steel. Duplex steels during machining are generally prone to mechanical strengthening Feed rate and cutting speed have statistically significant effect on surface roughness parameters Ra, Rz where increase of factors effect increase surface roughness but then feed rate is set to level 0.1 mm/rev factor cutting speed has smaller effect. **Esmail Soltani and Hesam Shahali** [7] made an attempt to model and optimizes hard turning AISI D3 Hardened steel using response surface methodology. The combined effects of four machining parameters, including cutting speed, feed rate, hardness and tool corner radius investigated. Tool corner radius and feed rate have most influence on surface roughness respectively. Among the interactions effect of feed rate-corner radius, hardness-corner radius and cutting speed-corner radius were significant on surface roughness respectively. **S Thamizhmanii S.Hasan**

[8] explained that when CBN inserts are treated cryogenically at -196 degree Celsius and the cutting parameters are cutting velocity and feed rate; Cryogenically treated CBN inserts produced less wear on titanium than AISI 440 C steel. Formation of flank wear in titanium alloy was low than AISI 440 C. **Zeng Dehuai1 et al** [9] used the Taguchi Method to Optimize the Cutting parameters of red copper tube namely cutting speed, feed rate, and depth of cut. An orthogonal array, the signal-to-noise (S/N) ratio, is employed to investigate the cutting characteristics using high speed steel W18Cr4V cutting tools. The experiment studies various factors impact on micro groove fin, gets the primary and secondary influence order of each factor to the surface roughness and optimal processing method. To reduce surface roughness, spindle speed should be appropriately reduced; the feed rate and feed per tooth should be increased. **Aman Aggarwal et al** [10] demonstrated Optimization of cutting parameters in CNC turning of P20 steel. The effect of optimization of cutting parameters (cutting speed, feed rate, depth of cut, nose radius and cutting environment) in CNC turning on power consumption is investigated. Taguchi method and response surface methodology was used to compare the power consumption. **Aman Aggarwal et al** [11] explained Optimization of multiple quality characteristics like tool life, cutting force, surface roughness and power consumption in CNC turning of P20 steel using liquid nitrogen as a coolant. Experiment results indicate that highest desirability could be obtained at low level of cutting speed, feed, depth of cut and high nose radius.

3 EXPERIMENTAL DETAILS:

3.1 Work Material

In this study work piece material P20 steel is selected. P20 is the most commonly used mold steel as it has many advantages as compared to other materials used for mold steel. It is used extensively for making injection moulds and occasionally compression moulds.P20 steel is having hardness of about 32-36 HRC and there is no need of subsequent heat treatments. It is a pre hardened mold steel with carbon content of 0.3 to 0.4 %. P20 steel is having higher sulphur content of about 0.35% which gives it excellent machinability. P20 is stronger, harder and abrasion resistant material allowing a longer life.

P20 steel is also used in making automobile shafts and live axles which transmit torque and have a sliding contact. The presence of chromium and nickel enhances the toughness and hardness of P20 steel. The high Nickel content of 1% is specially adapted to ensure a perfect homogeneity of structure for shafts, good polishability, adequate corrosion resistance and good machinability.

The chemical composition of P20 steel is shown in the Table1

Table1 Chemical composition of P20 steel

C	Si	Mn	S	Cr	Mo	Ni
0.35	0.45	0.85	0.35	0.03	1	0.8

3.2 Tool Insert

The cutting tool selected for machining P20 steel was TiN coated tungsten Carbide Insert of Sandvik Coromant make. The tungsten carbide insert used were of ISO coding CNMG 120408 and Tool holder used was CoroTum RC (Sandvik Coromant) of ISO coding DCLNR 2020K12. This quality of tool bits retains its hardness even at very high temperatures and is recommended where the generation of heat is very high and the tool should not get blunt at high temperatures. It results in less thermal cracks and increased tool life). Any wear pattern can be easily recognized with yellow TiN layer. The tool specifications are as follows.

Table 2 Tool specifications

Insert shape	Diamond 80°
Cutting edge length	12.8959mm
Insert thickness	4.7625mm
Corner radius	0.7938mm
Inscribed circle diameter	12.7mm
Weight	0.01kg
Cutting edge effective length	12.0959mm
Fixing hole diameter	5.165mm
Major cutting edge angle	95°

Table 3 Machining parameters and their levels.

Cutting parameters	Level 1	Level 2	Level 3
Spindle speed (RPM)	1000	1270	1600
Feed rate (mm/rev)	0.12	0.14	0.16
Depth of cut (mm)	0.05	0.1	0.175

Experimental set up

The experimental work was carried out at the company Haas Factory Outlet CNC Servicing Solutions (India) Pvt Ltd, Koparkhairane, Navi Mumbai on CNC turning machine Haas ST-10. The machine has chuck size of 6.5”, Max cutting diameter of 14.1” max spindle speed of 6000Rpm and a Spindle Max motor rating of 15HP with a Max torque of 102N-m@1300Rpm

Figure 1Experimental setup

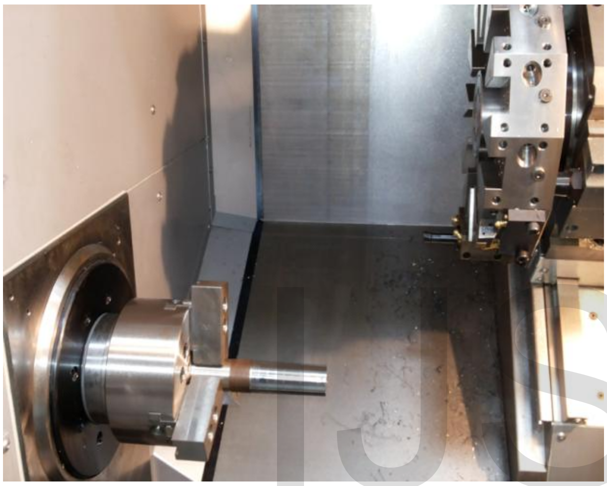


Figure 2 Chuck and Job arrangement

A surface roughness tester of Mitutoyo Surftest SJ-201P was used for measuring the surface roughness. The Surface roughness tester was capable of measuring Ra value up to 3 decimals with unit of micrometer.

The response variable selected to achieve better machining performance is surface roughness. Machining process parameters used in the investigation are Cutting speed, Depth of cut and Feed rate. In the present work, we apply the method of Taguchi for the optimization of process parameters in machining.

Figure 3 Surface Roughness Tester

After carrying out preliminary experiments using one factor at a time approach, the levels of varying parameters are decided to perform the main experiments. Taguchi L9 orthogonal array is being employed to carry out main experiments as compared to full factorial design of 27 experiments.

Taguchi's Technique:

Taguchi method uses a special design of orthogonal arrays to study the entire parameter space with a small number of experiments only. A loss function is then defined to calculate the deviation between the experimental value and the desired value. Taguchi recommends the use of the loss function to measure the performance characteristic deviating from the desired value. The value of the loss function is further transformed into a signal-to-noise (S/N) ratio h. There are three categories of the performance characteristic in the analysis of the S/N ratio, that is, the lower-the-better, the higher-the-better, and the nominal-the-better. The S/N ratio for each level of process parameters is computed based on the S/N analysis. Regardless of the category of the performance characteristic, the larger S/N ratio corresponds to the better performance characteristic. Therefore, the optimal level of the process parameters is the level with the highest S/N ratio ρ Furthermore, a statistical analysis of variance (ANOVA) is performed to see which process parameters are statistically significant. With the S/N and ANOVA analyses, the optimal Combination of the process parameters can be predicted. Finally, a confirmation experiment is conducted to verify the optimal process parameters obtained from the parameter design. In this paper, the cutting parameter design by the Taguchi method is adopted to obtain optimal machining performance in turning.

Smaller-is-the better (minimize):

$$S/N_S = -10 \log \left(\frac{1}{n} \sum_{i=1}^{n} y_i^2\right)$$

Where y is the average of observed data, n is the number of observations.

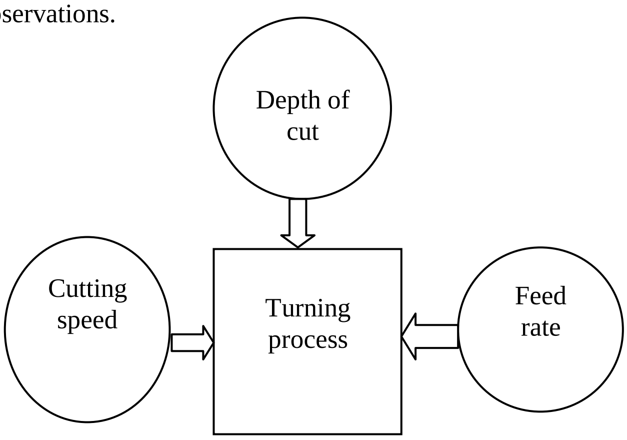


Figure 4 Factors affecting the turning process

Analysis of Mean of Sample:

- **By Taguchi Method:**

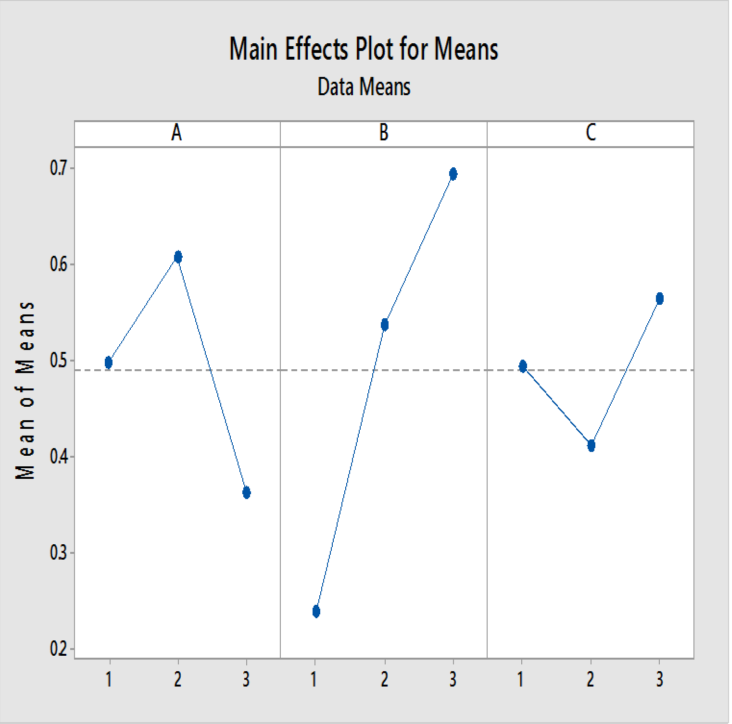
Response Table for Means
Quality characteristic: Surface Roughness
Quality characteristic Feature: Smaller the better

Table 4 Response Table for Means

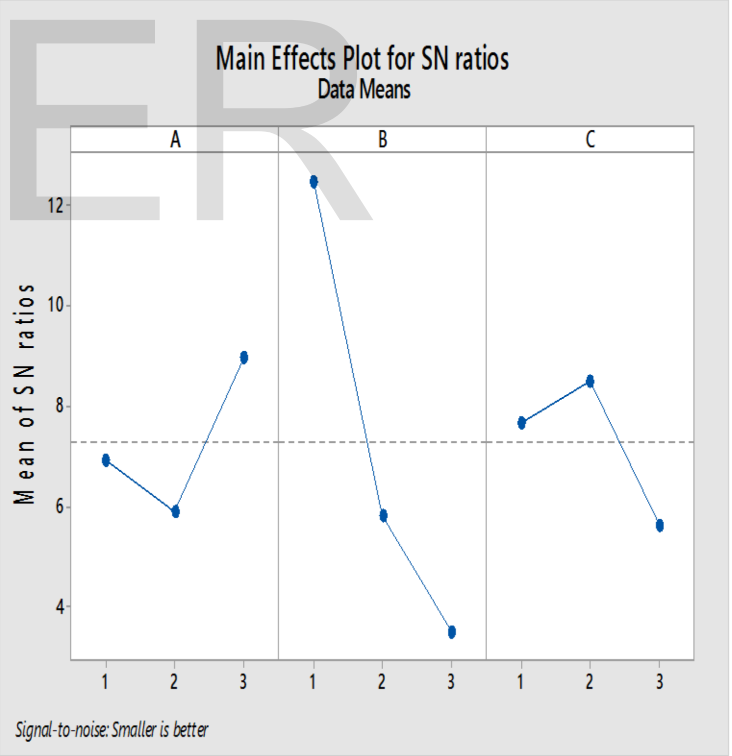
Level	A	B	C
1	0.5000	0.2400	0.4943
2	0.6100	0.5377	0.4120
3	0.3630	0.6953	0.5667
Delta	0.2470	0.4553	0.1547
Rank	2	1	3

Table 5 Surface roughness of P20 steel

Sr no	Cutting Parameters Level					
	Speed (RPM)	Feed (mm/rev)	Depth of Cut (mm)	Ra (µm)	SNRA	Mean
1	1000	0.12	0.05	0.230	12.765	0.230
2	1000	0.14	0.1	0.570	4.8825	0.570
3	1000	0.16	0.175	0.700	3.0980	0.700
4	1270	0.12	0.1	0.200	13.979	0.200
5	1270	0.14	0.175	0.710	2.9748	0.710
6	1270	0.16	0.05	0.920	0.7242	0.920
7	1600	0.12	0.175	0.290	10.752	0.290
8	1600	0.14	0.05	0.333	9.5511	0.333
9	1600	0.16	0.1	0.466	6.6323	0.466



Plot 1 Main effect plot for means



Plot 2 Main effect plot for Signal to Noise ratio

Regression Equation

Ra = 0.100 - 0.0685 **Cutting Speed** + 0.2277 **Feed rate** + 0.0362Depth **of cut**

Model Summary

S =0.41777 R-sq= 25.57% R-sq(adj)0.0%

Table 6 Coefficients for regression

Term	Coeff	SE Coef	T-Value	P-Value
Constant	0.1	0.255	0.39	0.710
A	-0.0685	0.0716	-0.96	0.383
B	0.2277	0.0716	3.18	0.0255
C	0.0362	0.0716	0.51	0.635

Result of means of sample

Plot 1 shows the means plot where the horizontal line is the value of the total mean of the means. Basically, smaller the means better is the quality characteristics for the material. As per the means analysis from graph the levels of parameters to be set for getting optimum value of Surface roughness are A3 B1C2.

Table 7 MS Excel solver for Surface roughness

Sr no	A	B	C	Ra for mean
1	0.363	0.240	0.4120	0.14469
2	0.500	0.5377	0.4943	0.206077
3	0.610	0.6953	0.5667	0.23704935

According to Regression analysis, entering a “t” table at 6 degrees of freedom (2 for cutting speed+ 2 for Feed rate + 2 for depth of cut) we find a tabulated “t” value of 0.39 (p=0.005). As shown in the Table 6, the calculated “ t ” value is -0.96 for Cutting speed and 3.18 for Feed rate and 0.51 for Depth of cut exceeds the tabulated value we say that, the difference between factor means at 95% level is significant. As “t”= - 0.96 for Cutting Speed we conclude that Surface Roughness value (Ra) by signal to noise ratio decreases with increase in Cutting Speed. The minimum surface roughness is 0.14469 from the table 7 as shown.

CONCLUSION:

The Taguchi method is used in this study to optimize the high speed CNC turning conditions of AISI P-20 steel. The cutting parameters optimization is carried out through experiments with minimum number of trials as against full factorial design. The results are summarized as follows:

(1) The factor/level combinations of A3 B1 C2 are the recommended optimum parameters, for high speed CNC turning.

(2) It can be concluded that the combination of the high level of cutting speed (200m/min) and low level feed of (0.1mm/rev) and a middle value of depth of cut 0.1mm yield the optimum result

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