

Experimental Investigations into CNC Lathe Turning operation by using Taguchi Methods

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ABSTRACT

CNC Turning Operation on P20 Material by Taguchi Method attempts on optimizing turning process under various machining parameters by Taguchi Method to develop or implement the quality of machined product. Taguchi optimization technology is applied to optimize cutting parameters in turning P20 material. The CNC turning machine is used to conduct experiments based on the Taguchi design of experiments (DOE). Signal to noise ratio (S/N) and analysis of variance (ANOVA) were implied to find the maximum material removal rate (MRR) and minimum surface roughness. The experiments results shows that the optimal combination of parameters for surface roughness are at variable speed, variable feed rate, variable depth of cut while for material removal rate are at variable spindle speed, variable feed rate, variable depth of cut. The optimum value of surface roughness (Ra) comes out to be 1µm. While the optimum value of the material removal rate (MRR) comes out to be mm³/min. Optimum results are finally varied with the help of conformation experiments.

Keywords: ANOVA, MRR, DOE, Ra, CNC.

1. INTRODUCTION

Taguchi method is a powerful tool for the design of high quality systems. It provides simple, efficient and systematic approach to optimize designs for performance, quality and cost. Taguchi method is efficient method for designing process that operates consistently and optimally over a variety of conditions. To determine the best design it requires the use of a strategically designed experiment. Taguchi approach to design of experiments is easy to adopt and apply for users with limited knowledge of statistics, hence gained wide popularity in the engineering and scientific community. The desired cutting parameters are determined based on experience or by hand book. Cutting parameters are reflected. Traditional experimental design methods are very complicated and difficult to use. Additionally, these methods require a large number of experiments when the number of process parameters increases [16, 17, and 18]. In order to minimize the number of tests required, Taguchi experimental design method, a powerful tool for designing high-quality system, was developed by Taguchi. This method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only Taguchi recommends analyzing the mean response for each run in the inner array, and he also suggests analyzing variation using an appropriately chosen signal-to-noise ratio (S/N). There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems; I) Smaller is better II) Larger is better III) Nominal is best

1.1 Review at Glance

1.2 Literature gap

Name of Author	Year	Operation	Material	Material Size	Methodology	Input Parameter		
						Spindle Speed	Feed Rate	Depth Of Cut
Sujit Kumar Jha	Jun-15	Turning Process	Aluminum	40 Mm Dia.	Taguchi, Anova	600, 800, 1000	0.10, 0.15, 0.20	0.5, 1, 1.5
D. Kanaka Raja & D. Anjan Reddy	Oct-14	Turning Process	Sae 8822 Alloy Steel		Taguchi, Anova	2557,204 1, 1693	0.06, 0.11, 1.27	0.6, 0.9, 1.2
Rahul Rajan	Feb-12	End Milling	Copper Bar	25*10 Mm Dia.	Taguchi Method	750, 1000, 1500	0.5, 0.15, 0.20	0.2, 0.4, 0.6
Dhole N.S & Prof. Naik G.R	Mar-12	End Milling	En33 Steel		Taguchi, Anova,	1005, 2010, 3140	0.1, 0.15, 0.2	0.05, 0.1 0.15
S. V. Algarsamy & Ravindra P	01-Jun-16	Turning Process	Aluminium Alloy 7075	25*115 Dia	Taguchi Method	500, 1000, 1500	0.1, 0.15,0.20	0.3, 0.5, 0.8
Vikas Mukhraiy a & Raj Kumar Yadao	Jan-14	Mig Welding Process	St-37 Steel Rod	20 Mm Dia	Taguchi Method			
Mahadev Naik & Ashish Gorule	2016	Turning Process	Aisi-410 Steel	18 Mm Dia	Taguchi Method	220,340, 480rev/M	0.1, 0.15, 0.2	0.3, 0.6, 0.9
M.Aghak hani & E.Mehrdad	Aug-11	Arc Welding	St-37 Steel Plates	200*100*6 Mm Dia.	Taguchi Method	220, 340, 480	0.1, 0.15, 0.2	0.3, 0.6, 0.9
Rama Rao.S & Padmanabhan. G	Jun - 2012	Electrochemical	Lm-6, Al/Sic	D=25, L=100 Mm	Taguchi , Anova	80, 350, 340	100, 360, 350	120, 370, 360
Sandhya Kumar & Rahul Kankane	Oct-15			L=1.6m	Taguchi Method			
Narendra Varma & Sikarwar	23-Sep-16	Turning Process	Ms Bar	D=50mm, L=100mm	Taguchi Method	620 Rpm	0.5mm/Rev	0.9mm
Sayak Mukharji & Anurag Kamal	2014	Turning Process	Sae 1020		Taguchi ,Anova	60, 62, 64, M/S	0.15, 0.2, 0.25mm/R ev	0.1, 0.15, 0.2

1. In most of the time the authors try to optimize the turning process.
2. After that they give their focus to optimize the following process and maximum time mild steel,
3. Copper, aluminum these type material can optimized

1.3 Objective

1. To study of CNC machining operation.
2. To Study optimization Of Taguchi Method
3. To find out the minimum machining time required
4. To find the maximum MRR.
5. To find out minimum surface roughness.

2. METHODOLOGY

2.1 Taguchi method

Traditional experimental design methods are very complicated and difficult to use. Additionally, these methods require a large number of experiments when the number of process parameters increases [16, 17, 18]. In order to minimize the number of tests required, Taguchi experimental design method, a powerful tool for designing high-quality system, was developed by Taguchi. This method uses a special design of orthogonal arrays to study the entire parameter space with small number of experiments only.

Taguchi recommends analyzing the mean response for each run in the inner array, and he also suggests analyzing variation using an appropriately chosen signal-to-noise ratio (S/N).

There are 3 Signal-to-Noise ratios of common interest for optimization of Static Problems;

(I) SMALLER-THE-BETTER:

$n = -10 \text{ Log}_{10} [\text{mean of sum of squares of measured data}]$ this is usually the chosen S/N ratio for all undesirable characteristics like “defects “etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined (like maximum purity is 100% or maximum Tc is 92K or minimum time for making a telephone connection is 1 sec) then the difference between measured data and ideal value is expected to be as small as possible. The generic form of S/N ratio then becomes, $n = -10 \text{ Log}_{10} [\text{mean of sum of squares of } \{\text{measured} - \text{ideal}\}]$

(II) LARGER-THE-BETTER:

$n = -10 \text{ Log}_{10} [\text{mean of sum squares of reciprocal of measured data}]$ this case has been converted to SMALLER-THE-BETTER by taking the reciprocals of measured data and then taking the S/N ratio as in the smaller-the-better case.

(III) Nominal –The -Best:

$$n = 10 \text{ Log}_{10} \frac{\text{Square of means}}{\text{Variance}}$$

This case arises when a specified value is MOST desired, meaning that neither a smaller nor a larger value is desirable.

2.2 DESIGN OF EXPERIMENT

In this study, three machining parameters were selected as control factors, and each parameter was designed to have three levels, denoted 1, 2, and 3 (Table). The experimental design was according to an L9 array based on Taguchi method, while using the Taguchi orthogonal array would markedly reduce the number of experiments. A set of experiments designed using the Taguchi method was conducted to investigate the relation between the process parameters and delamination factor. DESIGN EXPERT @ 16 Minitab software was used for regression and graphical analysis of the obtained data.

2.3 Design of experiment parameters and Levels

Symbol	Turning Parameters	Level 1	Level 2	Level 3
A	Cutting speed, (mm/min)	1000	1400	1800
B	Feed rate, (rev/min)	0.10	0.15	0.20
C	Depth of cut, (mm)	0.5	1	1.5

2.4 Material Used

Medium Steel alloy (P20) of Ø: 50 mm, length: 100 mm were used for the turning experiments in the present study. The chemical composition and mechanical and physical properties of P20 can be seen in table. The turning tests were carried out to determine the material removal rate under various turning parameters.

Chemical composition of P20 (Medium Steel alloy)

Sr. No	Property	Value
1	Density	7861 kg/m ³
2	Specific Gravity	7.86
3	Machinability	60-65 %
5	Thermal Conductivity	41.5 W/m ⁰ K
4	Melting Point	2600 °F
6	Modulus of Elasticity	207 GP
7	Modulus of Elasticity Tension	29 Mpa

3. Experimentation

Expt No.	Spindle Speed (rpm)	Feed rate (mm/rev)	Depth Of Cut (mm)	Machining Time sec	Initial Weight Before Cutting (Kg)	Final Weight Before Cutting (Kg)	MRR=Initial Wt. - Final Wt./Machining Time mm ³ /sec
1	1000	0.10	0.5	34	1.019	0.985	0.990
2	1000	0.15	1	24	1.021	0.961	0.981
3	1000	0.20	1.5	18	1.018	0.939	0.966
4	1400	0.10	0.5	25	1.018	0.987	0.979
5	1400	0.15	1	18	1.018	0.965	0.964
6	1400	0.20	1.5	14	1.014	0.939	0.947
7	1800	0.10	0.5	20	1.014	0.986	0.965
8	1800	0.15	1	14	1.019	0.963	0.950
9	1800	0.20	1.5	12	1.017	0.938	0.939

3.1 MRR Experiment results and Taguchi analysis

A series of turning tests was conducted to assess the influence of turning parameters on material removal rate in turning P20. Experimental results of the material removal rate for turning of P20 with various turning parameters are shown in table. Also gives S/N ratio for material removal rate. The S/N ratios for each experiment of L9 (3¹³) was calculated. The objective of using the S/N ratio as a performance measurement is to develop products and process insensitive to noise factor. Table 5 shows average effect response table. Response table signal to noise ration larger is better

Table for Means

Level	Spindle speed (rpm)	Feed Rate (mm/rev)	Depth of cut (mm)
1	0.9789	0.9777	0.9624
2	0.9633	0.9652	0.9661
3	0.9512	0.9505	0.9650
Delta	0.0277	0.0272	0.0037
Rank	1	2	3

Analysis of Variance Table

Source	Df	Adj Ss	Adj Ms	F-Value	P-Value
Regression	3	0.00227 1	0.000757	178.68	0
Spindle Speed (Rpm)	1	0.00115	0.00115	271.43	0
Feed Rate (Mm/Rev)	1	0.00111 1	0.001111	262.24	0
Depth Of Cut (Mm)	1	0.00001	0.00001	2.36	0.185
Error	5	0.00002 1	0.000004		
Total	8	0.00229 3			

Model Summary

S	R-sq	R-sq.(adj)	R-sq.(pred)
0.0020585	99.08%	98.52%	97.36%

Regression Equation

$$\text{MRR mm}^3/\text{sec} = 1.05119 - 0.000035 \text{ spindle speed rpm} - 0.2722 \text{ feed rate mm/rev} + 0.00258 \text{ depth of cut mm}$$

3.2 Result analysis of MRR

Minitab statistical software has been used for the analysis of the experimental work. The Minitab software studies the experimental data and then provides the calculated results of signal-to-noise ratio. The objective of the present work is to minimize machining time and maximize the MRR in turning process optimization. The effect of different process parameters on material removal rate and machining time are calculated and plotted as the process parameters changes from one level to another. The average value of S/N ratios has been calculated to find out the effects of different parameters and as well as their levels. The use of both ANOVA technique and S/N ratio approach makes it easy to analyze the results and hence, make it fast to reach on the conclusion. Table shows the experimental results for material removal rate and machining time and corresponding S/N ratios. Larger-the-better performance characteristic is selected to obtain material removal rate. From the response Table and Fig.it is clear that cutting speed is the most influencing factor followed by feed rate and depth of cut for MRR. The optimum for MRR is cutting speed of 1000 rpm. Feed rate of 0.15mm/rev and depth of cut of 1.5mm.

5.2 SURFACE ROUGHNESS

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 molding greatly depends on finishing of the moulds. Surface roughness is one of the important factors for the materials used for making molds 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. A surface roughness tester of Mitutoyo

Surface SJ-201P was used for measuring the surface roughness. The Surface roughness tester was capable of measuring Ra value up to 3 reading taken.

6. Conclusion

The present study was carried out to study the effect of input parameters on the material removal rate. The following conclusions have been drawn from the study:

1. The Material removal rate is mainly affected by cutting speed and feed rate. With the increase in cutting speed the material removal rate is increases & as the feed rate increases the material removal rate is increases.
2. From ANOVA analysis, parameters making significant effect on material removal rate feed rate, and interaction between feed rate & cutting speed were found to be significant to Material removal rate for reducing the variation.
3. The parameters considered in the experiments are optimized to attain maximum material removal rate. The best setting of input process parameters for defect free turning (maximum material removal rate) within the selected range is as follows:
 - a. Cutting speed i.e. 1000m/min.
 - b. Feed rate i.e. 0.15mm/rev.
 - c. Depth of cut should be 1.5mm.
4. The Taguchi method is used in this Study to optimize the high speed CNC Turning conditions of AISI P-20 steel.
5. The factor/level combinations of A2 B1 C3 are the recommended optimum Parameters, for high speed CNC Turning.
6. It can be concluded that the combination of the high level of cutting speed (1400 rpm) and low level feed of (0.10mm/rev) and a middle value of depth of cut 1.5mm yield the optimum result

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