An Optimization of Turning Process Parameters for Surface Roughness for SS 316L material by using Taguchi Method: A Review

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Abstract: This study identify the problem occurs during turning which involves more component rejection due to surface roughness. The objective of this paper is to obtain the optimal setting of turning process parameters in order to reduce the rejection rate during machining. Initially, the various problems that occur in the components during machining are investigated. The investigation is done with the help of Quality Assurance department in a manufacturing industry. During investigation, it is found that the main reason of rejection is surface roughness which occur in component is due to wrong CNC parameter. The process parameters considered for study purpose are- cutting speed, depth of cut, feed rate at three levels and required output is surface roughness. To obtain the optimal process parameter combination, optimization is carried out by the Signal-to-Noise (S/N) ratio analysis of Taguchi method using L9 Orthogonal Array. An analysis of variance (ANOVA) is used to present the influence of process parameters on surface roughness. Results obtained by Taguchi method and by ANOVA method, are compared and found that they match closely with each other. In this way, the optimum levels of process parameters can be predicted. Finally it is concluded that, in order to reduce the rejection rate due to surface roughness, the best process parameter combination which is derived through this study must be followed during the production process.
This works involves a case study of largest manufacturer of stainless steel long products which mostly uses 304L and 316L stainless grade of SS.
Key words: Taguchi method, orthogonal array, surface roughness

I. INTRODUCTION

The turning operation is a basic metal machining operation that is used widely in industries dealing with metal cutting. The selection of machining parameters for a turning operation is a very important task in order to accomplish high performance. By high performance, we mean good machinability, better surface finish, lesser rate of tool wear, higher material removal rate, faster rate of production etc.

The surface finish of a product is usually measured in terms of a parameter known as surface roughness. It is considered as an index of product quality. Better surface finish can bring about improved strength properties such as resistance to corrosion, resistance to temperature, and higher fatigue life of the machined surface. In addition to strength properties, surface finish can affect the functional behavior of machined parts too, as in friction, light reflective properties, heat transmission, ability of distributing and holding a lubricant etc. Surface finish also affects production costs. For the aforesaid reasons, the minimization of the surface roughness is essential which in turn can be achieved by optimizing some of the cutting parameters.

I.I MATERIAL STUDY

SS 316L is an austenitic Chromium-Nickel stainless steel with superior corrosion resistance. The low carbon content reduces susceptibility to carbide precipitation during welding. This permits usage in severe corrosive environments such as isolator diaphragms.

NOMINAL COMPOSITION
Chromium 17.2%, Manganese 1.6%, Nickel 10.9%, Carbon .02%, Molybdenum 2.1%, Iron Balance

PHYSICAL PROPERTIES:
Density - 0.29 lbs/cu.in
Melting Point (Approx.) - 1370° C
Electrical Resistivity @ R.T. - 74 Microhm·cm
Thermal Expansion Coefficient - 16.0 x 10-6/°C (0°to100° C)
Thermal Conductivity @ 100° C - 16.3 W/m· K
Magnetic Attraction Annealed - None
Cold Rolled - Slight
Magnetic Permeability - 1.02 Max.

GENERAL INFORMATION:
The alloy can be formed from the annealed temper by stamping and deep drawing. Joining is accomplished by brazing and welding. The Molybdenum is the alloy composition provides excellent strength up through 800° F in applications.

I.II OBJECTIVES OF PRESENT WORK

a) To study the influence/effect of machining parameters viz. speed, feed and depth of cut, on the surface roughness of machined material.
b) To determine optimum machining parameter settings for the chosen tool/work combination so as to minimize the surface roughness.
c) To reduce the production cost by optimizing the cutting parameters as such after machining is done there are no requirement of other finishing process.
d) To reduce the time and material wastage that occurs during machining by trial and error method.

I.III RESEARCH METHODOLOGY

The methodology used for the research work is as per details as shown in figure 1 as given below:

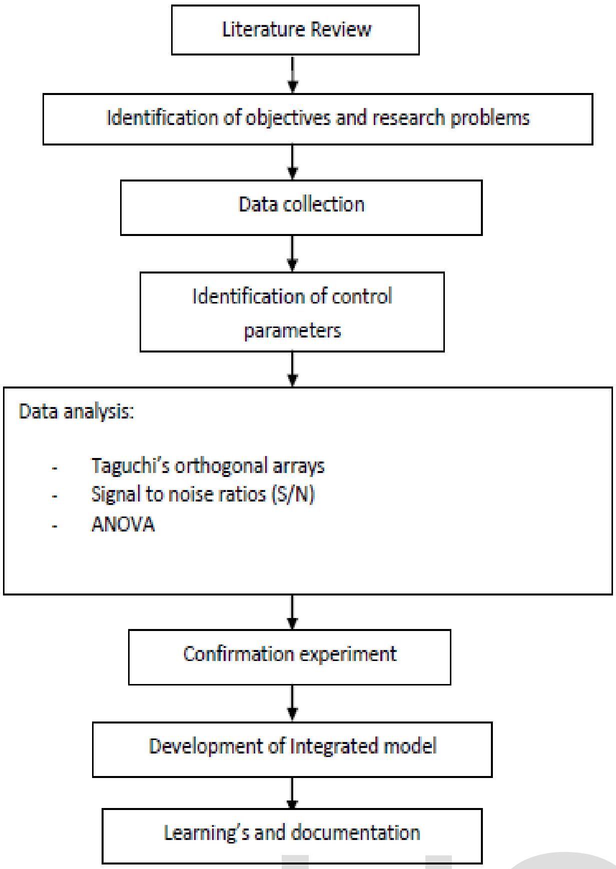

Fig1: Flow chart for Reserch Methodology

II. LITERATURE REVIEW

Thamizhmanii, S., et al. (2007) He used the coated ceramic tool and Taguchi's mixed level L18 orthogonal array to analyzed the optimum cutting conditions to get the lowest surface roughness in turning SCM 440 alloy steel. Results were analyzed in Design-Expert software. It was found that depth of cut was a significant factor then feed in consideration of lowest surface finish.

Natarajan, C., et al. (2010) [2] tests were performed in dry condition on C26000 metal and designed an artificial neural network (ANN) to predict the surface roughness using Matlab 7 software. The cutting parameters were spindle speed, feed rate and depth of cut. A total of 36 specimens were experimented. Matlab 7 is used for matching actual roughness values with the predicted roughness values.The percentage of deviation between the roughness values was found to be 24.4%.

Babu, V. Suresh, et al. (2011) [3] developed a second order model to predict the surface roughness in machining EN24 steel alloy using Response Surface Method. Two level three cutting parameters i.e. cutting speed, feed rate and depth of cut were considered for the experiment. 3D plots were drawn to find out the optimum setting for minimum surface roughness.

Sahoo, P. (2011) [4] studied the roughness characteristic of surface profile created by turning AISI 1040 steel in CNC machine. The optimization of surface roughness was done using response surface method and genetic algorithm. Depth of cut, feed rate and spindle speed were considered as the machining parameters. A three level rotatable composite design was selecting for developing the mathematical model for predicting the surface roughness. it was found that roughness values decreases with increases in depth of cut and spindle speed whereas roughness value increases with feed rate.

Barik, C. R., and Mandal, N. K., (2012) [5] studied the characteristics of surface roughness in turning of EN31 alloy by optimization of machining parameters using Genetic Algorithm. 3D response plots were formed based on response surface method quadratic models. It was found that the surface roughness decreases with decrease in feed rate at constant speed. And surface roughness also decreases with decrease in depth of cut keeping speed constant. The predicted values were found to be in acceptable zone w.r.t. the experimental results.

Davis, R. and Alazhari, Mohamed (2012) [6] worked to optimized the cutting parameters (spindle speed, feed and depth of cut) in dry turning of mild steel with 0.21% C and 0.64% Mn with a HSS cutting tool. Taguchi's L27 orthogonal array was conducted to find out the lowest surface roughness. ANOVA and Signal to Noise ratio were utilized to find out the performance characteristics. Among the three cutting parameters only feed was found to be significant.

Kumar, K. A., et al. (2012) [7] analyzed the optimum cutting conditions to get the lowest surface roughness in face turning by regression analysis. The cutting parameters investigated are spindle speed, feed and depth of cut on EN8 alloy. The performance and the effect of parameters on surface roughness were determined by multiple regression analysis and ANOVA using MINITAB. From this paper it was observed that cutting speed and feed were the significant factors affecting surface roughness.

Rodrigues, L.L.R., et al. (2012) [8] studied the effect of feed, speed and depth of cut on the surface roughness as well as cutting force in turning mild steel with HSS cutting tool. They suggested that feed and depth of cut has significant effect on surface roughness and cutting force.

Sharma, N., et al. (2012) [9] applied L18 orthogonal array to optimize the surface roughness in turning. ANOVA and signal to noise ratio were applied to study the performance characteristics in turning AISI 410 steel bars using TiN coated P20 and P30 cutting tool. The cutting parameters considered were insert radius, depth of cut, feed and cutting speed. It was found that the insert radius and feed rate has significant effect on surface roughness with 1.91 and 92.74% contribution respectively.

Somashekara, H.M., and Swamy, N. L., et al. (2012) [10] obtained an optimal setting for turning Al6351-T6 alloy for optimal surface roughness. A model was generated for optimal surface roughness using regression technique. From ANOVA and S/N ratio, cutting speed was found to be highest significant parameter followed by feed and depth of cut.

Yadav, U. K., et al. (2012) [11] enquired the effect of machining parameters (speed, feed and depth of cut) on optimization of surface roughness in turning AISI 1045 steel alloy. The experiments were conducted on stallion 100HS CNC lathe using Taguchi's L27 orthogonal array. From ANOVA it was found that feed has the maximum contribution of 95.23% on the surface roughness than cutting speed.

Bala Raju, J., et al. (2013) [12] investigated the effect of cutting parameters in turning mild steel and aluminum using HSS cutting tool. It was carried out to achieve better surface finish and to decrease power requirement by flattening the cutting force in machining.

Krishan Prasad, D.V.V. (2013) [13] conducted full factorial design consisting of 243 experiments considering three machining parameters and two tool geometrical parameters to determine the impact of these parameters on surface roughness. The machining parameters were speed, feed and depth of cut whereas the tool geometrical parameters were back rake angle and side rack angle with three levels each. The metal used for turning was mild steel with HSS cutting tool. It was found that feed is the only significant factor during this experiment.

Koura, M. M., et al. (2014) [14] established a surface roughness model by using artificial neural network. The effect of the parameters i.e., cutting speed, feed rate and depth of cut on surface roughness in turning of mild steel using carbide inserts was inspected. It was concluded that increase in feed rate increases the roughness whereas increases in cutting speed decreases the roughness.

Lodhi, B. K. and Shukla, R. (2014) [15] attempted to optimize the surface roughness and MRR in machining AISI 1018 alloy with Titanium coated Carbide inserts. Among spindle speed, feed rate and depth of cut the optimal setting was obtained. Taguchi's L9 orthogonal array was used to experiment in a CNC lathe machine

Mohan, R., et al. (2014) [16] optimized the machining parameters (cutting speed, feed rate and depth of cut) for lower surface roughness. AISI 52100 steel alloy also known as bearing steels were used for optimization. Carbide inserted cutting tool with nose radius 0.80 were used for machining. Taguchi's L9 orthogonal arrays were used to design the experiment. Contribution of each factor was analysed by ANOVA. It was found that feed has significant effect on surface roughness.

Shunmugesh, K., et al. (2014) [17] studied the machining process in turning of 11sMn30 alloy using carbide tip insert in dry condition. It was found that the feed rate is the most significant factor to affect surface roughness other than cutting speed and depth of cut.

Sharma, S. K. and Kumar, S. (2014) [18] applied Taguchi orthogonal design to optimize the setting of cutting parameters in surface roughness. The experiments were conducted in CNC machine taken the cutting parameters as cutting speed, feed and depth of cut using coated carbide single point cutting tool. This experiment showed that feed has immense effect on surface roughness in turning mild steel 1018 with coated carbide single point cutting tool.

Quazi, T., and More, Pratik Gajanan (2014) [19] utilized Taguchi method to optimize the surface roughness in turning EN8, EM31 and mild steels. It was observed that feed rate has highest effect on surface roughness for all the three alloys.

Francis, Vishal, et al. (2014) [20] optimized the cutting parameters of mild steel (0.18% C) in turning to obtain the factors effecting the surface roughness and MRR. To study the influence of cutting parameters they applied ANOVA and Signal to Noise.

Rajpoot, Bheem Singh, et al. (2015) [21] used Response Surface Methodology to scrutinize the effect of cutting parameters like cutting speed, feed and depth of cut on average surface roughness and material removal rate during turning of Al 6061 alloy.

III. PROBLEM IDENTIFICATION

Here the optimization of turning process is often achieved by trial-and-error method based on the shop floor experiences by determining the certain parameters of the process. But this does neither guarantee the quality nor the machining economics. Therefore a general optimization plan is required to avoid trial runs on machine and wastages.

Following defect commonly observed during CNC turning:
1. Built-up edge formation
2. Surface roughness problem.
3. Dimension problem due to wrong CNC parameter

Reason for rejection of material during turning in CNC:
1. Wrong CNC parameter
2. Cutting tool insert wear
3. Operator negligence
4. Machine offset problem
5. Waviness/ vibration on surface

During the investigation with the help of QA department it is clear that MRR and surface roughness both are affected by cutting parameter. But In our case study machining of flange by using carbide cutting tool insert, we observed that material rejection is more due to surface roughness.

The main problem is the need to increase manufacturing quality and at the same time to decrease production costs. There are many variables which affect the quality and production costs of the product, including cutting parameters, tool materials, tool geometry, coating technology, lubricants, etc. Consequently, companies are forced to operate by using the trial and error method. The optimization of controllable variables can make a considerable contribution towards solving the problem.

Traditionally, the empirical trial-and-error method has been used to get the best parameter combination, through a series of experiments; however, this approach is tedious, expensive, and time consuming. Design of experiments (DOE) techniques like the Taguchi method can optimize the process parameters with minimum number of experimental trials. Taguchi offers a simple and systematic approach to obtain optimal setting of the process parameters. Therefore, in present study, Taguchi optimization methodology is applied.

IV. METHODOLOGY

Taguchi method was developed by Dr. Genechi Taguchi, as a researcher at the electronic control laboratory in Japan. He carried out significant research on DOE techniques in the late 1940's. He proposed that optimization of process parameters should be carried out in three-step approach- system design, parameter design, and tolerance design. System design deals with innovative research, looking for what factors and levels should be. Parameter design is used to obtain the optimum levels of process parameters to improve the performance of process/products by adjusting levels of factors. Finally, tolerance design aims to determine the control characteristics for each factor level identified in earlier studies. The parameter design is the key step in Taguchi method to achieving high quality without increasing cost. The steps included in Taguchi parameter design are: selecting the proper orthogonal array (OA) according to the numbers of controllable factors (parameters); running experiments based on the OA; analyzing the data; identifying the optimum condition; and conducting confirmation trials with the optimal levels of all the parameters. To select an appropriate orthogonal array for experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is. The degrees of freedom for the orthogonal array should be greater than or at least equal to those for the process parameters. For three parameters each at three levels, the degrees of freedom are six. Once the degrees of freedom required are known, the next step is to select an appropriate orthogonal array to fit the specific task. A three level orthogonal array (L9 3^3) with nine experimental runs (total degrees of freedom = 9-1 = 8) is selected for the present study. Orthogonal array (OA) is nothing but the shortest possible matrix of combinations in which all the parameters are varied at the same time and their effect and performance interactions are studied simultaneously. With the selection of (L9 3^3) orthogonal array, using three parameters and three levels for each, the numbers of experiments required are nine, which in classical combination method using full factorial experimentation would require 27 numbers of experiments to get the influencing parameters. Thus, by using Taguchi method, based on orthogonal arrays, the numbers of experiments can be reduced. Taguchi method employs the S/N ratio to identify the quality characteristics applied for engineering design problems. The S/N ratio characteristics can be divided into three types: lower-the-better, larger-the-better, and nominal-the-better.

V.EXPERIMENTAL DETAILS

A. Selection of Process Parameter levels and Response Factor:

There are three input controlling parameters (cutting speed, feed rate and depth of cut) selected with their three levels, shown in table 1:

Cutting Parameter	Level 1	Level 2	Level 3
Cutting Speed	A1	A2	A3
Depth of cut	B1	B2	B3
Feed	C1	C2	C3

Table 2: Cutting parameter with their three value

B. Design of Experiments:

The design of experiment is carried out by Taguchi methodology using Minitab 16 Software. In this technique the main objective is to optimize the surface roughness that is influenced by various process parameters. Since three controllable factors and three levels of each factor are considered L9 (3^3) Orthogonal Array is selected for this study. Table 2 shows the layout of experiments to be carried out according to Taguchi L9 Orthogonal Array.

Experiment Number	Cutting Parameter and value		
	Cutting speed	**Depth of cut**	**Feed**
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

Table 2: The layout of experiments

VI. ANALYZING AND EXAMINING RESULT

i. Determine the parameters signification (ANOVA)-Analysis of variance
ii. Conduct a main effect plot analysis to determine the optimal level of the control factors.
iii. Execute a factor contribution rate analysis.
iv. Confirm experiment and plan future application

VII. CONCLUSION AND FUTURE WORK

The paper has demonstrated an application of the Taguchi method for investing the effects of cutting parameters on surface roughness in turning SS316L metal. L9 orthogonal array has been constructed for three different levels of cutting parameters, which are speed, feed and depth of cut. For Experimental design extended taguchi method will be used for optimization process & find out number of readings. To identify the significant factor and to find out percentage contribution of each input parameter for obtaining optimal conditions we will use ANOVA method. Using the signal to noise ratio and mean ANOVA calculations, the optimum output characteristics will be predicted by Minitab.

REFERENCES

1. S. Thamizhmanii, S. Saparudin and S. Hasan, ―Analyses of Surface Roughness by Turning Process using Taguchi Method,‖ *Journal of Achievements in Materials and Manufacturing Engineering*, Volume 20, pp. 503 – 506, January-February 2007
2. C. Natarajan, S. Muthu and P. Karuppuswamy, ―Investigation of Cutting Parameters of Surface Roughness for a Non Ferrous Material using Artificial Neural Network in CNC turning‖ *Journal of Mechanical Engineering Research,* Vol. 3, pp. 1-14, January 2011.
3. Suresh Babu, S. Sriram Kumar, R. V. Murali and M. Madhava Rao, ―Investigation and validation of optimal cutting parameters for least surface roughness in EN24 with response surface method,‖ *International Journal of Engineering, Science and Technology,* Vol. 3, pp. 146 – 160, November 2011.
4. Sahoo, P., ―Optimization of Turning Parameters for Surface Roughness using RSM AND GA,‖ *Advances in Production Engineering & Management,* Volume 6, pp. 197 – 208, 2011.
5. C. R. Barik and N.K. Mandal, ―Parametric effect and Optimization of Surface Roughness of EN31 in CNC dry Turning,‖ *International Journal of Lean Thinking,* Vol. 3, pp. 54 – 66, December 2012.
6. Rahul Davis and Mohamed Alazhari, ―Optimization of Cutting Parameters in Dry Turning Operation of Mild Steel,‖ *International Journal of Advanced Research in Engineering and Technology,* Volume 3, pp. 104-110, July-December 2012.
7. K. Adarsh Kumar, Ch. Ratnam, B.S.N. Murthy, B. Satish Ben and K. Raghu Ram Mohan Reddy, ―Optimization of Surface Roughness in Face Turning Operation in Machining of EN-8,‖ *International Journal of Engineering Science & Advanced Technology,* Volume-2, pp. 807 – 812, Jul-Aug 2012.
8. Rodrigues L.L.R., Kantharaj A.N., Kantharaj B., Freitas W. R. C. and Murthy B.R.N., ―Effect of Cutting Parameters on Surface Roughness and Cutting Force in Turning Mild Steel,‖ *Research Journal of Recent*

Sciences, Vol. 1, pp. 19- 26, October 2012.

9. Nitin Sharma, Shahzad Ahmad, Zahid A. Khan and Arshad Noor Siddiquee, ―Optimization of Cutting Parameters for Surface Roughness in Turning,‖ *International Journal of Advanced Research in Engineering and Technology,* Volume 3, pp. 86 – 96, January- June 2012.
10. H.M. Somashekara and N. Lakshmana Swamy, ―Optimizing Surface Roughness in Turning Operation using Taguchi Technique and ANOVA,‖ *International Journal of Engineering Science and Technology,* Vol. 4,pp. 1967 – 1973, May 2012.
11. Upinder Kumar Yadav, Deepak Narang and Pankaj Sharma Attri, ―Experimental Investigation And Optimization Of Machining Parameters For Surface Roughness In CNC Turning By Taguchi Method,‖ *International Journal of Engineering Research and Applications,* Vol. 2, pp. 2060 – 2065, July-August 2012.
12. BalaRaju. J, Anup Kumar. J, Dayal Saran. P and C.S. Krishna Prasad Rao, ―Application of Taguchi Technique for Identifying Optimum Surface Roughness in CNC end Milling Process,‖ *International Journal of Engineering Trends and Technology,* Volume 2, pp. 103 – 110, March 2015.
13. Vishal Francis, Ravi. S. Singh, Nikita Singh, Ali. R. Rizvi and Santosh Kumar, ―Application of Taguchi Method and ANOVA in Optimization of Cutting Parameters for Material Removal Rate and Surface Roughness in Turning Operation,‖ *International Journal of Mechanical Engineering and Technology,* Volume 4, pp. 47-53, May - June 2013.
14. D.V.V. Krishan Prasad, ―Influence of Cutting Parameters on Turning Process Using ANOVA Analysis,‖ *Research Journal of Engineering Sciences,* Vol. 2, pp. 1 – 6, September 2013.
15. M. M. Koura, T. H. Sayed and A. S. El-Akkad, ―Modeling and Prediction of Surface Roughness,‖ *International Journal of Engineering Research & Technology,* Vol. 3, pp. 694-699, July 2014.
16. Brajesh Kumar Lodhi and Rahul Shukla, ―Experimental Analysis on Turning parameters for Surface roughness and MRR,‖ *Journal of Emerging Technologies and Innovative Research,* Volume 1, pp. 554 -557, Nov 2014.
17. Rony Mohan, Josephkunju Paul C and George Mathew,―Optimization of Surface Roughness of Bearing Steel during CNC Hard Turning Process,‖ *International Journal of Engineering Trends and Technology,* Volume 17, pp. 173 – 175, Nov 14.
18. Shunmugesh K., Panneerselvam K., Pramod M. and Amal George, ―Optimization of CNC Turning Parameters with Carbide Tool for Surface Roughness Analysis Using Taguchi Analysis,‖ *Research Journal of Engineering Sciences,* Vol. 3, pp. 1 – 7, June 2014.
19. Sushil Kumar Sharma and Sandeep Kumar, ―Optimization of Surface Roughness in CNC Turning of Mild Steel (1018) using Taguchi method,‖ *International Journal of Engineering Research & Technology,* Vol. 3, pp. 2928 – 2932, January – 2014.
20. Taquiuddin Quazi and Pratik gajanan more, ―Optimization of Turning Parameters Such as Speed Rate, Feed Rate, Depth of Cut for Surface Roughness by Taguchi Method,‖ *Asian Journal of Engineering and Technology Innovation*, Volume: 02 , pp. 5 – 24, March 2014.
21. Bheem Singh Rajpoot, Dharma Ram Moond and Shrivastava, Sharad, ―Investigating the Effect of Cutting Parameters on Average Surface Roughness and Material Removal Rate during Turning of Metal Matrix Composite Using Response Surface Methodology,‖ *International Journal on Recent and Innovation Trends in Computing and Communication,* Volume: 3, pp. 241 – 247, January 2015.