A Review on Optimization of Machining Parameters in Turning of AISI 1018 carbon Steel Bar

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Abstract - *The competitive manufacturing industry demands that companies aim to deliver high-quality, low-cost products within the shortest possible time. Advance manufacturing systems, including CNC machines, are essential for achieving high accuracy and efficiency. This study leverages the Taguchi method with an L16 Orthogonal Array to optimize machining parameters, including RPM, feed rate, and depth of cut, for the turning operation of AISI 1018 steel. The aim is to reduce surface roughness, a key quality parameter. The results reveal that RPM and feed rate have a significant impact on surface roughness, with the optimal settings achieving a reduction to 1.37 µm.*

Keywords *- Optimization, CNC Turning, AISI 1018 Steel, Taguchi Method, Surface Roughness*

I. INTRODUCTION

1.1. Background

In today's competitive manufacturing landscape, companies aim to deliver high-quality, cost-effective products in minimal time to meet customer demands. To achieve these goals, automated and flexible manufacturing systems are widely adopted. Among these, computerized numerical control (CNC) machines play a pivotal role due to their ability to ensure high accuracy and reduce processing time. In turning operations, the selection of cutting parameters is critical for enhancing cutting performance. Traditionally, these parameters are chosen based on practical experience or handbook references. However, cutting parameters have a direct influence on surface roughness, surface texture, and the dimensional accuracy of the final product. Surface roughness, a vital quality indicator, not only defines the technological quality of a product but also significantly impacts manufacturing costs. It represents the geometric features of machined surfaces and is intrinsically tied to surface texture. To form a surface roughness is a complex, process-dependent phenomenon. To optimize cutting parameters, several mathematical models using statistical regression and neural network techniques have been developed. These models forms the relation in cutting parameters and their performance, leading to the formulation of an objective function with constraints. Optimization techniques are then employed to determine the ideal parameters, but this process demands considerable expertise and experience. Taguchi method is an alternative approach to efficiently identify the optimal cutting parameters. This systematic methodology provides a practical and effective solution for improving machining performance.

1.2. Objective

The study focuses on optimization of surface roughness value in the turning operation of M.S. Bright steel using Tungsten carbide inserts by employing Taguchi's L16 orthogonal array. It aims to find out the optimal levels of cutting parameters, including cutting speed, feed rate, and depth of cut, while also analyzing their percentage contributions. Furthermore, the research investigates the application of the Taguchi method in engineering, showcasing its effectiveness in determining the best combination of cutting parameters to achieve optimal surface roughness performance in a turning operation.

1.3. Scope

Given considerations have to follow for best result in experimentation:

1. The workpiece used for machining is AISI 1018 carbon steel bars.
2. The cutting experiment is conducted on an ACE MICROMATIC CNC turning machine located at Supriya Industries Machine Workshop.
3. A three-level L16 orthogonal array is used as a reference to set up the experiment.
4. The orthogonal array, signal-to-noise ratio, and analysis of variance are employed to analyze the performance characteristics in turning operations.
5. The Taguchi method is applied to determine the optimum cutting parameters for surface roughness.

1.4. Problem Statement

Identify the performance characteristics of AISI 1018 carbon steel and select the process parameters using Taguchi's single-objective optimization of various machining parameters related to surface roughness.

II. LITERATURE REVIEW

i. Dr. Genichi Taguchi(1999) formulate different methods at the time of Japanese post - World War. At the time of war resources were less and financial support was minimum, Reconstruction demands of Japanese industry were huge. This period of Japanese requires rapid learning and more strive in improvement While constrained by usual raw materials and limited capital. From an engineering background, Dr Taguchi develops new statistics technique with the help of his Technical knowledge in statistics and advanced mathematics and engineering expertise[1]

ii. B.S. Rajpoot et.al.(2015) have studied the effects of cutting speed, feed and depth of cut on surface roughness and Material Removal Rate while turning of AA6061by using Response Surface Methodology. He studied the effect of every factor individually on surface roughness face centered design based on Response Surface Methodology. Surface roughness was measured at three different points. Experimentation was carried out on Design Expert 8.0.4.1 software, In this software twenty experimented samples were examined methodically to get the surface roughness & Material Removal Rate. ANOVA was performed to analyse the regression model which was develop for evaluating surface roughness for an accuracy of 95%. He got the results that surface roughness and Material Removal Rate are the significant factors amongst the three cutting parameters.[2]

iii. J.B.Raju et al.(2015) observed that while turning mild steel and aluminium by using High speed steel tool which was done to get better surface finish and to decrease power requirement. For experimentation he used 2k factorial techniques. To carry out the effect of cutting parameters ANOVA was used. Multiple regression analysis was used to develop cutting forces, Feed was found to be significant factor effecting on both surface roughness and cutting force.[3]

iv. M.A. El Hakim et al.(2015) analysed the effect of machining parameter on cutting force component in hard turning of AISI T15 high speed steel. The cutting force during the turning of the alloy steel was remarkably affected by the type of the chip produced.[4]

v. S.A. Lawal et al.(2015) done the experimentation by turning of AISI 4340 steel and found the effect of cutting fluids on cutting force components using Taguchi method. He observed that cutting speed and cutting feed were significant factors on cutting force measurements.[5]

vi. S.C.Borse(2015) was used Taguchi method to minimize the surface roughness and maximize the metal removal rate by using SAE 52100 steel with carbide inserts. He got the results which indicate that the feed rate is mostly changes with respect to surface roughness of the machined surface.[6]

vii. D. R. Deore(2015) done the optimization of machining parameters by using Taguchi Method for minimum cutting forces.EN 19 steel is used for turning operation on lathe machine. He uses ANNOVA technique and get the result that Depth of cut is the significant factor for thrust force, and feed rate is the significant factor for feed force. To estimate the value of performance level for any parameter level multiple regression equation was formed.[7]

viii. Lodhi done the analysis on optimization of the surface roughness & material removal rate during machining of AISI 1018 alloy with Titanium coated carbide inserts.He used input parameters that is Spindle speed, feed rate & depth of cut . L9 orthogonal array is used for experimentation on CNC Lathe machine. Lowest and highest level of surface roughness & material removal rate got respectively. ANOVA was used to obtain the most significantly effecting factor which was spindle speed for surface roughness & material removal rate with 75.295% & 78.173% respectively.

III. METHODOLOGY

Methodology of project is based on experimentation and analysis part. In experimentation during turning operation the observations are made on the cutting parameters from the start of the experiment till get the desired surface finish. Further analysis of the results have to made to find an optimal cutting parameter for surface roughness.

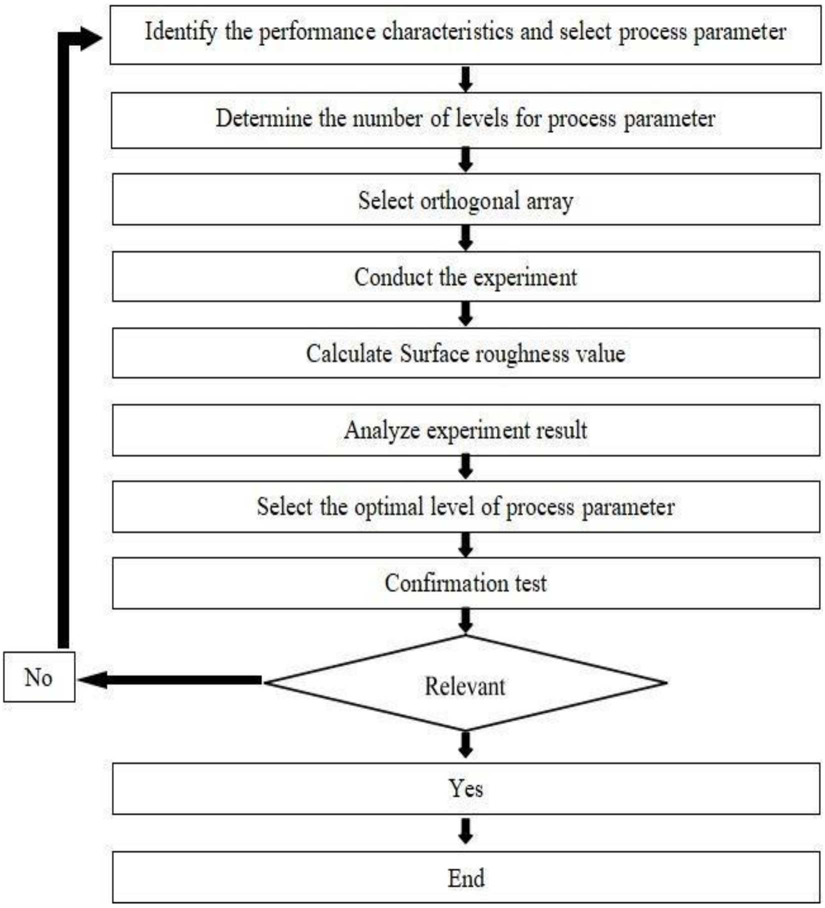

Figure 1. Methodology flow chart

This study uses the Taguchi L16 orthogonal array to design experiments. The experiment was conducted on an ACE Micrometric CNC turning machine using AISI 1018 steel bars having 32 mm diameter and 60 mm length. The cutting tool used was a carbide insert having a nose radius of 0.8 mm. The machining parameters considered were:

1. **Cutting Speed (RPM)**: - 800, 1200, 1600, 2000
2. **Feed Rate (mm/rev): -** 0.1, 0.2, 0.3, 0.4
3. **Depth of Cut (mm): -** 0.2, 0.4, 0.6, 0.8

Surface roughness measurements were taken using a Mitutoyo SJ-210 surface roughness tester, and the average of three readings was recorded for each experiment.

3.1. Procedure of measuring RA value

Following are the Steps for Measuring Surface Roughness Using Mitutoyo SJ-210.

1. Clean and stabilize the workpiece
2. Turn on and calibrate the SJ-210.
3. Place the stylus at the starting point, perpendicular to the surface
4. Select cut-off length, evaluation length, and measuring speed.
5. Start the measurement and let the stylus traverse the surface.
6. Read and document the surface roughness (Ra) value.
7. Clean the stylus and store the tester properly.

Figure 2. Actual measuring process

3.2. Taguchi Method

The Taguchi method involves a specially constructed orthogonal array to reduce the number of experiments required. In this study, the L16 orthogonal array was used, which allows the investigation of three factors each having four levels. The signal- to-noise (S/N) ratio was used to determine the optimal levels of the machining parameters. Lower values are desirable for surface roughness.

IV. RESULTS AND DISCUSSION

The experiments revealed significant insights into the effects of machining parameters on surface roughness. To identify the significant factors and their interactions the analysis of variance (ANOVA) was performed.

4.1. Experimental Results

The number of experiment was conducted by using the Taguchi method to optimize machining parameters of turning AISI 1018 steel provided significant insights into the factors affecting surface roughness. The following are the detailed results obtained from the study:

4.1.1. Experimental Setup

Material: - AISI 1018 Steel
Machine: - ACE Micrometric CNC TurningMachine
Tool: - Carbide Insert with 0.8 mm Nose Radius
Parameters: -

1. Cutting Speed (RPM): -800, 1200, 1600, 2000
2. Feed Rate (mm/rev): - 0.1, 0.2, 0.3, 0.4
3. Depth of Cut (mm): - 0.2, 0.4, 0.6, 0.8

4.2. Surface Roughness Measurements

Surface roughness (Ra) is measured using a Mitutoyo SJ-210 surface roughness tester. The average of three readings was recorded for each experiment.

Table 1. Surface roughness measurement.

Speed (rpm)	Feed (mm/rev)	Depth of cut (mm)	Machining time	R.A Value (µm)
800	0.1	0.2	1min 2sec	3.27
800	0.2	0.4	56 Sec	7.58
800	0.3	0.6	36sec	5.68
800	0.4	0.8	32 sec	5.23
1200	0.1	0.4	63sec	2.78
1200	0.2	0.2	32sec	3.89
1200	0.3	0.8	25sec	2.0
1200	0.4	0.6	18sec	2.49
1600	0.1	0.6	46sec	2.58
1600	0.2	0.8	29sec	2.39
1600	0.3	0.2	18sec	3.31
1600	0.4	0.4	16sec	3.50
2000	0.1	0.8	38sec	1.3
2000	0.2	0.6	22sec	2.5
2000	0.3	0.4	16sec	2.14
2000	0.4	0.2	14sec	3.65

4.3. Analysis

The analysis of the experimental results was conducted using ANOVA to determine the significant factors influencing surface roughness. The main effects plots for S/N ratios indicated the optimal levels of each parameter.

Optimal Cutting Speed: - 2000 RPM
Optimal Feed Rate: - 0.10 mm/rev
Optimal Depth of Cut: - 0.8 mm

These optimal settings resulted in the lowest surface roughness of 1.37 µm. The significant findings from the experiments are as follows:

Cutting Speed: - As cutting speed increases surface roughness is decrease. The highest speed of 2000 RPM yielded the best surface finish.
Feed Rate: - A lower feed rate was associated with reduced surface roughness. The optimal feed rate was found to be 0.10 mm/rev.
Depth of Cut: - While the depth of cut had a lesser impact compared to cutting speed and feed rate, the optimal depth was identified as 0.8 mm for achieving the best surface quality.

4.4. Discussion

1. For speed =2000rpm, feed=0.1mm/rev and depth of cut = 0.8mm and its value is. The optimum that is minimum value of Ra=1.37(µm) is found
2. Minitab 14 software is used for obtaining L16 orthogonal array
3. Orthogonal array has significantly reduced number of experiments to be conducted
4. It is found that speed and feed are more influencing factor for Ra than depth of cut
5. Machining time is also considered while machining the components.

V. CONCLUSION

The application of the Taguchi method to optimize machining parameters in the CNC turning of AISI 1018 steel has proven to be highly effective. This study focused on three primary parameters: cutting speed, feed rate, and depth of cut, aiming to minimize surface roughness, which is a critical quality attribute in many engineering applications. By utilizing an L16 orthogonal array, we were able to systematically investigate the effects of these parameters and identify the optimal settings.

The experimental results revealed that cutting speed and feed rate significantly impact surface roughness, with the depth of cut having a lesser but still notable effect. The analysis of variance (ANOVA) further confirmed that the cutting speed and feed rate are the most influential factors. The optimal machining parameters identified in this study were a cutting speed of 2000 RPM, a feed rate of 0.10 mm/rev, and a depth of cut of 0.8 mm. These settings achieved a minimum surface roughness of 1.37 µm, demonstrating a substantial improvement in surface finish.

The practical implications of these findings are significant for the manufacturing industry. By adopting the optimal parameters identified, manufacturers can achieve higher quality surfaces, reduce the need for secondary finishing processes, and lower production costs. The reduction in surface roughness not only enhances the aesthetic appeal of the machined components but also improves their performance and longevity in service.

Moreover, the use of the Taguchi method provides a structured and efficient approach to parameter optimization. This method reduces the number of experiments needed, saving both time and resources while ensuring robust and reliable results. The success of this study underscores the value of the Taguchi method in machining process optimization and its potential application to other materials and machining operations.

In conclusion, this study demonstrates that careful optimization of machining parameters using the Taguchi method can significantly enhance the quality of machined surfaces. The findings provide a valuable reference for CNC machinists and engineers seeking to improve their manufacturing processes. Future research could expand on this work by exploring multi-objective optimization, incorporating additional quality attributes such as material removal rate and tool wear, and applying the method to other materials and machining techniques. Through continued exploration and application of these optimization techniques, the manufacturing industry can achieve greater efficiency, quality, and competitiveness.

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