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Machining Parameter Evaluation and Optimization for 080M40 Steel Turning

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ABSTRACT*:* The purpose of this study was to optimize and assess the machining parameters for turning 080M40 steel on a lathe. The use of tool materials and process parameters for machining forces for a chosen parameter range and the estimation of ideal performance characteristics are the subjects of this study. Provide a process for machining parameters and cutting force optimization. This array can handle three-level process parameters and has 26 degrees of freedom. There are twenty-seven possible combinations of cutting parameters, each of which is assigned to a column. Consequently, the L9 orthogonal array can be used to study the entire parameter space with just twenty-seven experiments. Three levels of analysis were performed on each parameter to investigate the nonlinear relationship between process parameters. The orthogonal array (OA) technique, a fractional factorial with a pair-wise balancing property, served as the foundation for the designed experiments. Depending on the objective function, an appropriate S/N ratio is selected in order to examine the variation in response. In the current study, a quality characteristic that results from process parameter variations within a designed range to minimize cutting force is a force on the tool. Thus, the S/N ratio for the "Lower the better" response type was applied, and it is provided by.

Keywords: Orthogonal array, ANOVA, Taguchi method, turning, optimization and evaluation.

Introduction

This research offers an experimental examination of the impact of different tool- and process-dependent parameters on cutting forces. Researchers R. W. Lanjewar, P. Saha, U. Datta, A. J. Banarjee, S. Jain, and S. Sen examine how various tool materials and process parameters can be used to achieve the lowest possible machining forces within a given parameter range. In order to determine the ideal machining parameter, comparative studies are conducted to choose the process parameters for turning operation on AISI 304 austenitic stainless steel on auto sharpening machine.[1] In order to stay competitive in the market, modern manufacturers rely on their production staff and manufacturing engineers to quickly and efficiently set up manufacturing processes for new products.

Daniel Kirby discovered that Taguchi Parameter Design is an effective technique for enhancing the output and quality of manufacturing processes, making it a potent tool for overcoming this difficulty. The Taguchi method is used to determine the ideal cutting parameters for surface roughness in turning, as demonstrated by M. Nalbant, H. Gokaya, and G. Sur. Surface roughness is taken into account when optimizing the insert radius, feed rate, and depth of cut the three cutting parameters. Using coated and uncoated cemented carbide G. Akhyar, C.H. Che Haron, and J.A. Ghani investigated the application of Taguchi optimization methodology to optimize cutting parameters in turning Ti-6% Al-4% V extra low interstitial at high cutting speeds and dry cutting conditions (Alam et al., 2025). Ersan Aslan, Necip Camuscu, and Burak Birg ren conducted research indicating that Al2O3-based ceramics are among the best materials for cutting tools when it comes to hardened steels because of their high hardness and resistance to wear. On the other hand, their extreme brittleness typically causes erratic outcomes and unexpected catastrophic failures. The current study describes an experimental investigation that uses Taguchi techniques to accomplish this. Using an orthogonal array and the analysis of variance (ANOVA), the combined effects of three cutting parameters cutting speed, feed rate, and depth of cut on two performance measures flanking wear (VB) and surface roughness (Ra)—were examined.

A general framework for parameter optimization in metal cutting processes is proposed for the advantages of choosing an appropriate approach. Indrajit Mukherjee and Pradip Kumar Ray discussed the application potential of several modeling and optimization techniques in metal cutting processes, classified under several criteria, and have been critically appraised. Lui´s Figueira and J. Paulo Davim looked into that, a plan of experiments was conducted in turn using orthogonal arrays. in tool steel workpieces using predetermined cutting parameters (Hossen, 2023). A combined method utilizing an analysis of orthogonal arrays and Variance Analysis (ANOVA) was utilized to examine the Steel for cold work tools' machinability. Manna Alakesh, Sandeep Salodkar outlines the steps to get the unit-considering machining conditions for turning operations production costs as a measurable function. In this work, the Taguchi method a potent instrument for designing experiments—is also employed to optimize the cutting parameters in order to improve surface finish and determine the best parameter for cost evolution during turning. [8] Zhang Xuepinga, Gao Erweia, and C. Richard Liu study how cutting depth, speed, and feed rate affect the formation of subsurface compressive residual stress. Through a planned experiment that utilized a Taguchi L9 array, they adjusted process parameters within a practical range. X-ray diffraction was used to assess and examine the residual stresses that resulted. Once the ideal set of process parameters was determined, residual stress was measured using the smaller-is-better objective function. [9] Using the Grey relational analysis method, Chorng-Jyh Tzeng, Yu-Hsin Lin, Yung-Kuang Yanga, and Ming-Chang Jeng investigated the optimization of CNC turning operation parameters. Nine experimental runs using the Taguchi method's orthogonal array were carried out (Hossen & Pauzi, 2025a).

The depth of cut is the most significant controlled factor for the turning operations according to the weighted sum grade of the roughness average, roughness maximum, and roundness. The analysis of variance (ANOVA) is also used to determine the most significant factor. According to Tzeng Yih-fong, a set of ideal turning parameters was developed in order to achieve high dimensional precision and accuracy during the turning process. For the common tool steels SKD-11 and SKD-61, the Taguchi dynamic approach in conjunction with a suggested ideal function model was used to optimize eight control factors. The experimentally designed L18 orthogonal array included the following control factors: coolant, cutting speed, feed, depth of cut, coating type, chip breaker geometry, nose radius, and insert shape. It was demonstrated by Farhad Kolahan, Mohsen Manoochehri, and Abbas Hosseini that the surface roughness is chosen as the process output performance metric. The Taguchi method is used to collect experimental data. The optimal sets of cutting parameters and tool geometry specifications have then been identified based on signal-to-noise (S/N) ratio. The surface roughness of AISI1045 steel parts may be reduced by using these parameter values. Sijo M.T. and Biju.N. discovered that ideal cutting parameters are necessary for the effective use of machine tools (Hossen & Salleh, 2024).

The optimization of turning process parameters is a laborious and intricate process. The Taguchi parameter optimization methodology is used in this paper to turn cutting parameters into optimal values. When turning En24 steel (0.4 % C), Hari Singh looked into the best possible settings for cutting speed, feed, and depth of cut. This could lead to an improvement in the tool life of TiC-coated carbide inserts. Hari Singh and Pradeep Kumar devised an experimental method to determine the ideal turning process parameter setting that could result in the best tool wear for titanium carbide-coated inserts when EN 24 steel is being machined. [16] Regression and Taguchi techniques are two statistical modeling techniques that have been used to create models. According to Kompan Chomsamutr and Somkiat Jongprasithporn, parameter design can be used to achieve the best cutting design for turning while still meeting product specifications. The issue with manufacturing spare parts is finding the best milling parameters and applying those results to the cost and life cycle of the goods. By experimenting with design parameters and using the Taguchi method for analysis, the research methodology was examined. The Taguchi approach is one of the most widely used techniques for turning process optimization, with the cutting force being the most frequently chosen target quality characteristic to examine the impact of different process parameters on the final product. This research had two objectives (Hossen & Salleh, 2024). The first was to present a methodical process for turning machine process control utilizing Taguchi parameter design. The second was to show how to apply the Taguchi parameter design to determine the best cutting force performance and assessment when using a specific set of cutting parameters during a turning operation.

Methodology

It is necessary to compute the total degrees of freedom to choose an appropriate orthogonal array for the experiments. The number of comparisons between process parameters required to identify which level is superior and precisely how much superior it is is known as the degrees of freedom. The next step is to choose an appropriate orthogonal array to fit the particular task after the required degrees of freedom are known. Essentially, the orthogonal array's degrees of freedom ought to be larger than or on par with the process parameters. An L9 orthogonal array was utilized in this research.

This array can handle three-level process parameters and has 26 degrees of freedom. There are twenty-seven possible combinations of cutting parameters, each of which is assigned to a column. Consequently, the L9 orthogonal array can be used to study the entire parameter space with just twenty-seven experiments. Three levels of analysis were performed on each parameter to investigate the nonlinear relationship between process parameters (Hossen et al., 2023). The orthogonal array (OA) technique, a fractional factorial with a pair-wise balancing property, served as the foundation for the designed experiments. Depending on the objective function, an appropriate S/N ratio is selected in order to examine the variation in response. In the current study, a quality characteristic that results from process parameter variations within a designed range to minimize cutting force is a force on the tool. Thus, the S/N ratio for the "Lower the better" response type was applied, and it is provided by.

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

Where, i = no. of trial,

Yi= measured value of quality characteristic for the trial condition,

n= no. of repetitions.

The formula was used to determine the signal-to-noise ratios under each of the nine experimental scenarios. Affected factors can be distinguished based on mean response and S/N ratio. Table 3 displays the experimental setup with the L9 orthogonal array for the three cutting parameters.

Data Analysis

Three categories of performance characteristics exist, as previously mentioned: lower-the-better, higher-the-better, and nominal-the-better. The lower-the-better cutting force performance characteristic should be chosen in order to achieve the best possible machining performance. The experimental findings for cutting forces and the associated S/N ratio using Eq. (1) are displayed in Table 1.

Because of the orthogonal experimental design, it is then feasible to isolate the impact of every cutting parameter at various levels. It is possible to calculate the mean S/N ratio for every cutting parameter level. The mean S/N response table for cutting force is a summary of the mean S/N ratio for each cutting parameter level. Table Four Furthermore, Table 5 lists the total mean S/N ratio for each of the nine experiments.

Table 1 Result for individual characteristic S/N ratio, S/N ratio for average output quality parameter

Parameter	S/N ratio for Thrust force (F_Z)			S/N ratio for Feed Force (F_Y)		
	L1	L2	L3	L1	L2	L3
Tool shape and material (A)	-47.35	-47.17	-48.39	-40.73	-39.9	-41.27
Cutting speed (B)	-46.87	-46.63	-49.4	-40.34	-39.77	-41.78
Depth of cut (C)	-45.53	-47.41	-49.96	-39.44	-39.82	-42.63
Feed (D)	-44.7	-48.19	-50.02	-37.99	-41.94	-41.96

Results and Discussion

The average values of performance characteristics for each parameter at various levels were computed to determine the mean response (Table 2). The thrust force Z was found to be minimum at the first level of parameter C (depth of cut), the first level of parameter D (feed), the second level of parameter A (tool shape and material), and the second level of parameter B (cutting speed). Similar findings have been made regarding the minimum feed force Y at the second level of parameters A (tool shape and material), B (cutting speed), C (depth of cut), and D (feed).

Table 2 ANOVA for thrust force

Source	Sum of Squares (SS)	Degrees of freedom (f)	Variance (V)	F-ratio	Pure sum of squares (SS')=Sa- (ve*Fa)	Contribution on (P), %
A	16390.09	2	8195.05	41.29	15993.14	3.789
B	77927.53	2	38963.77	196.32	77927.53	18.46
C	150391.07	2	75195.54	378.87	150391.07	35.63
D	173819.75	2	86909.88	437.89	173819.75	41.18
E (error)	3572.52	18	198.47		3969.47	0.94
T(total)	422100.96	26			422100.96	100

Conclusion

The second level of parameters A, B, C, and D, as well as the first level of parameter D, are the ideal levels of parameters for the minimum thrust force Z. This suggests that the ideal combination of parameters to obtain the lowest thrust force Z when turning 080M40 8 bar is A2, B2, C1, and D1. The second level of parameters A, B, C, and D, as well as the first level of parameter D, are the ideal levels of parameters for the minimum feed force Y. This suggests that the optimal combination of parameters at designated levels A2, B2, C1, and D1 will result in the lowest thrust force Z when turning an 080M40 8 bar.

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Data Availability: The author holds all the data employed in this study and is open to sharing it upon reasonable request.

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