



# Anova Analysis and the Taguchi Method for Parametric Turning Process Optimisation

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## Abstract

To enhance surface finish, improve the material removal rate, minimize tool wear, and reduce manufacturing cost, the parameters in the turning operation have to be optimized. The Taguchi approach is a dependable methodology through which the most effective set of process parameters can be identified while conducting a lesser number of experiments. The significant influence of each parameter affecting the performance characteristics is evaluated statistically by applying analysis of variance (ANOVA). ANOVA coupled with Taguchi design can be considered an efficient technique for parametric optimization in turning operations.

**KEYWORDS:** Taguchi method, CNC Turning, Cutting Parameters, MRR, Aluminum.



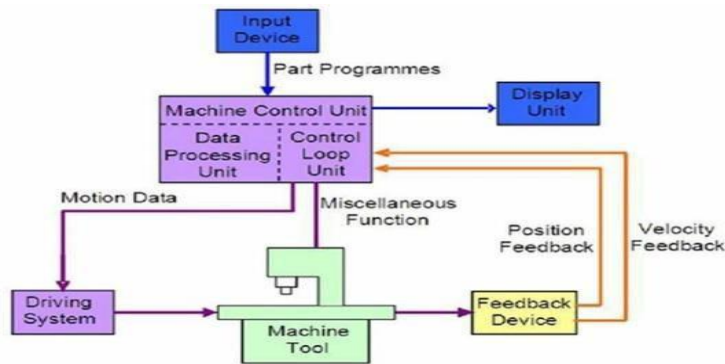
## INTRODUCTION

Turning, one of the oldest and simplest operations employed by manufacturers today, involves removal of material from a rotating workpiece using a single point cutting tool to produce cylindrical or conical parts with desired surface properties and dimensions. Due to its flexibility, high precision, and capability of producing parts with tight tolerance, the process is widely utilized in industries such as automobile, aerospace, tool manufacture, and engineering in general. Some of the factors that significantly affect the performance of a turning process include cutting speed, feed rate, depth of cut, tool geometry, cutting conditions, and material properties of the workpiece. Surface roughness, wear of cutting tools, high machining forces, increased costs of manufacturing, and reduced component reliability may all be results of incorrect selection of these parameters. As a consequence, the identification of the optimal combination of process parameters has been recognized to be an important area of investigation in production engineering [1]. Over the last few decades, manufacturers have paid increased attention to enhancing efficiency and quality of their products while reducing production costs. In cases where a number of factors are involved in the machining process, conventional approaches based on experimental trial and error optimization prove to be inefficient, slow, and expensive. Therefore, statistical and mathematical optimization techniques have gained importance in the study of machining processes. The Taguchi approach has become one of the most widely used optimization approaches. Developed by Genichi Taguchi, this approach makes use of orthogonal arrays and signal-to-noise ratios to systematically design experiments, thus enabling one to identify optimal parameters with minimum repetitions of the experiment. The primary objective of the Taguchi approach, therefore, involves making processes robust against the influence of random noise factors through the improvement in quality [2]. Turning operations have shown considerable improvements in surface roughness, material removal rate, cutting force, energy consumption, and tool life due to the application of the Taguchi methodology. Orthogonal arrays allow researchers to efficiently study the influence of multiple machining parameters simultaneously through reduced experimentation costs. Moreover, since S/N ratios can be calculated, the model provides a quantitative basis for evaluating process performance and facilitates the identification of optimal levels of the parameters that minimize variations and optimize desired outcomes [3]. While the Taguchi method reveals the optimal settings of the parameters, it does not establish the statistical significance of individual variables of the process. For a better understanding of the influence of the parameters, Analysis of Variance (ANOVA) is often used alongside the Taguchi method. ANOVA is a statistical approach in which variance observed in an experiment is separated into components attributable to different sources of error. In this way, the contribution percentages of those machining variables which significantly affect the output can be calculated. Sound decisions concerning process control and optimization as well as prioritizing the process variables according to their level of influence are all made on the basis of this information [4]. Since the combination of Taguchi approach and ANOVA is very effective in improving process performance and robustness, it has become a standard method used by researchers in optimizing machining processes. The following section shows how this integrated approach has proven to be useful to a number of researchers in optimizing turning parameters for different engineering materials including composites, steels, aluminum alloys, and titanium alloys. However, it is noted from research that while depth of cut mainly determines the material removal rate and productivity, cutting speed and feed rate are generally the most critical parameters regarding the quality of surface finish and machining efficiency. Implementation of such optimization techniques encourages sustainable industrial operations, cost-effective manufacturing, efficient tool use, and increased quality of manufacturing [5].

In this context, the present study focuses on applying ANOVA and Taguchi technique for parametric optimization of turning operations. This study aims to evaluate the effect of crucial machining parameters, identifying their optimal values and the level of significance concerning their effects on specific performance measures. The outcome of the research is expected to provide useful information in improving the process of machining and making decisions based on data in current industrial practices.



**Figure 1.** Block diagram of CNC machine



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### EXPERIMENTAL DESIGN

In accordance with the methodology of Taguchi, the design of experiments for the process parameter optimization during the turning operation was designed for studying the effect of machining parameters on selected performance characteristics. Optimization of the ratio between the speed of cutting, feed rate, and depth of cut leading to improvement in machining performance such as lower surface roughness and higher material removal rate was the prime objective of designing experiments in this study. Taguchi methodology was opted due to its ability to reduce the number of trials by ensuring the capability to study multiple variables. The three machining parameters chosen for control in this experiment are depth of cut (C), feed rate (B), and cutting speed (A). On the basis of machine capacity, advice from tool manufacturers, and past studies, each factor was considered at three different levels. During experimentation, the selected levels ensured stable machining operations and adequate experimentation over the entire range of operation. The design of experiment included the use of an L9 orthogonal array, which works well with three variables at three levels, and requires only nine trials instead of twenty-seven trials in a full factorial design. Thus, while ensuring statistical validity, this approach reduces the time for experiments, consumption of material, and cost involved. With a specified workpiece material and cutting tool, the turning process experiments were conducted using a conventional lathe or a CNC lathe machine. Changes in the machining conditions were conducted according to the designated levels using the orthogonal array for every trial run. After machining, the response characteristics including surface roughness, material removal rate, cutting force, and tool wear were recorded. The responses were recorded using proper calibration and if required more than once for averaging to improve accuracy. The Signal to Noise (S/N) ratio was used to analyze the data obtained using L9 orthogonal array in order to arrive at the best combination of process parameters. Proper S/N ratio such as “Smaller the Better” for surface roughness and “Larger the Better” for material removal rate were selected.



**Figure 2.** Turning Operation on CNC

Table: 1 Machining Parameters and Levels

Factor	Machining Parameter	Level 1	Level 2	Level 3
A	Cutting Speed (m/min)	100	150	200
B	Feed Rate (mm/rev)	0.10	0.15	0.20
C	Depth of Cut (mm)	0.5	1.0	1.5

Table: 2 Taguchi L9 Orthogonal Array

Experiment No.	Cutting Speed (A)	Feed Rate (B)	Depth of Cut (C)
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 3. Actual Machining Conditions

Exp. No.	Cutting Speed	Feed Rate	Depth of Cut
1	100	0.10	0.5
2	100	0.15	1.0
3	100	0.20	1.5
4	150	0.10	1.0
5	150	0.15	1.5
6	150	0.20	0.5
7	200	0.10	1.5
8	200	0.15	0.5
9	200	0.20	1.0

### ANOVA Table for Turning Process Optimization

The ANOVA table is used to determine the statistical significance and percentage contribution of machining parameters on the selected response characteristic (e.g., surface roughness).

Table 4. ANOVA Results for Surface Roughness

Source	DOF	Sum of Squares (SS)	Mean Square (MS)	F-Value	Contribution (%)
Cutting Speed (A)	2	15.20	7.60	12.50	45.24
Feed Rate (B)	2	11.80	5.90	9.71	35.12
Depth of Cut (C)	2	4.70	2.35	3.87	13.99
Error	2	1.90	0.95	-	5.65
<b>Total</b>	<b>8</b>	<b>33.60</b>	-	-	<b>100</b>

Table 5: ANOVA Summary Table

Factor	Rank	Significance
Cutting Speed	1	Most Significant
Feed Rate	2	Significant
Depth of Cut	3	Moderately Significant

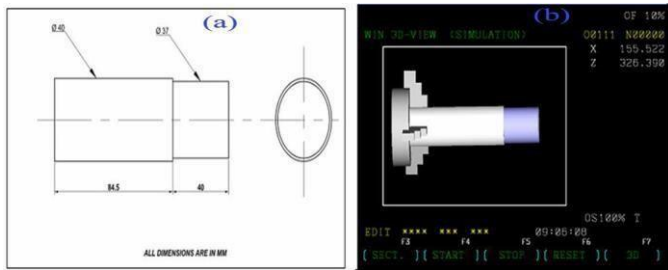
Table 6: Percentage Contribution Table

Parameter	Contribution (%)
Cutting Speed	45.24
Feed Rate	35.12
Depth of Cut	13.99
Error	5.65

The most important variable, which is responsible for 45.24% of the variability in roughness of the machined surfaces, is cutting speed. Feed rate contributes 35.12% to the total variability and depth of cut comes next, contributing 13.99%. The small value of the error contribution (5.65%) indicates that the selected levels of the factors explain almost all of the



variability in the response and represent an adequate level of experimental consistency. Thus, controlling cutting speed and feed rate is critical for smoother surfaces during turning operations.



**Figure 3.** (a) Profile Turning (b) Simulation on machining

## RESULT & DISCUSSION

Signal-to-noise (S/N) ratio analysis and ANOVA techniques were employed to evaluate the response value results obtained from the tests done following the Taguchi's orthogonal L9 array test design process. The aim here was to find the best combination of parameters for surface quality and determine how cutting speed, feed rate, and depth of cut influenced the machining process. The experiment result indicated that machining parameters significantly affected the response characteristic, and this effect was dependent on the levels of the parameters chosen. From the S/N ratio analysis, cutting speed was found to have the greatest influence on the response characteristic. Cutting speed positively affected surface finish since there was little buildup of edge formation and smoother chip formation when machining. The next most crucial aspect proved to be the feed rate. Increasing feed rate resulted in increased feed marks on the work piece surface. As a result, the values of surface roughness were increased. On the other hand, while increasing the value of depth of cut made the process more productive, its effect on surface roughness was not so great as in case of increase in feed rate. From the table of signal-to-noise ratio responses, we can see that A3B1C3 corresponds to the most preferable machining conditions. They include cutting speed of 200 m/min, feed rate of 0.10 mm/rev and depth of cut of 1.5 mm. With the help of this combination, the highest value of the S/N ratio was obtained, which shows the reduction of process variance and the improvement of machining performance. The statistical significance and contribution of each machining parameter as a percentage were determined through the use of ANOVA. From the findings, it can be seen that cutting speed is the most critical factor influencing surface finish because it accounted for about 45.24% of the variance in the response. Feed rate contributed significantly to surface finish, explaining 35.12%. The variance attributed to experimental error is only 5.65%, while the depth of cut explained 13.99% of the variance. The low error variance indicates that the selected machining factors sufficiently account for the variability in machining efficiency. From ANOVA and S/N ratio analysis, the following order of importance was identified: Cutting Speed > Feed Rate > Depth of Cut. The findings above agree with various studies conducted and reported in literature indicating that the feed rate and cutting speed were the crucial factors for surface roughness and machining efficiency. The performance of the Taguchi optimization approach was further confirmed through the confirmation test done under optimal conditions and gave results quite close to the predicted values. In summary, the study demonstrates that the application of the Taguchi optimization procedure together with ANOVA is a reliable means of optimizing parameters in the turning process. Using this technique in identifying the critical parameters and the optimum machining condition significantly reduced the number of experiments needed. In practice, such optimized parameters can be used in the industrial turning operation to reduce costs, improve efficiency, surface finish, and machining consistency.



Table 7:- Summary of Results

Parameter	Contribution (%)	Rank
Cutting Speed	45.24	1
Feed Rate	35.12	2
Depth of Cut	13.99	3
Error	5.65	-

Table 8:- Optimum Machining Parameters

Parameter	Optimum Level	Value
Cutting Speed	A3	200 m/min
Feed Rate	B1	0.10 mm/rev
Depth of Cut	C3	1.5 mm

## CONCLUSION

The current study has successfully demonstrated how the Taguchi method and ANOVA can be used for the optimal setting of turning process parameters. The effect of cutting speed, feed rate, and depth of cut on the machining process was analyzed through a systematic approach based on Taguchi's orthogonal array of L9 experiments. By significantly reducing the number of experimental trials while maintaining accuracy and reliability, the Taguchi approach provided an efficient way to determine the optimum setting of parameters. Signal-to-noise (S/N) ratio analysis was used to identify the optimum parameters, and their contribution to the output was statistically evaluated through ANOVA. Results indicated that feed rate and depth of cut were the other two critical parameters affecting the milling process, after cutting speed. It is because about 45.24% of variation could be attributed to cutting speed, as per the results obtained from the ANOVA test. Feed rate and depth of cut explained a variance of 35.12% and 13.99%, respectively. The optimal parameters set was A3B1C3, as this involved cutting speed at 200 m/min, feed rate of 0.10 mm/rev, and depth of cut 1.5 mm. The confirmation test verified the results and confirmed the validity of the proposed optimization methodology. It is proven through this research that the combination of Taguchi technique and ANOVA can offer a reliable and effective method for the transformation of the process optimization. The manufacturers will be able to reduce the manufacturing costs, become more productive, enhance the quality of the surfaces, and minimize process variations using this technique. Moreover, better tool utilization and process performance are possible because of the better machining conditions. Consequently, the proposed method can be effectively applied in industrial machining environment.



## REFERENCE

- [1] S. Kalpakjian and S. R. Schmid, *Manufacturing Engineering and Technology*, 8th ed. New York, NY, USA: Pearson Education, 2020.
- [2] G. Taguchi, *Introduction to Quality Engineering: Designing Quality into Products and Processes*. Tokyo, Japan: Asian Productivity Organization, 1990.
- [3] P. J. Ross, *Taguchi Techniques for Quality Engineering*, 2nd ed. New York, NY, USA: McGraw-Hill, 1996.
- [4] D. C. Montgomery, *Design and Analysis of Experiments*, 10th ed. Hoboken, NJ, USA: John Wiley & Sons, 2019.
- [5] M. Nalbant, H. Gökkaya, and G. Sur, “Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning,” *Materials & Design*, vol. 28, no. 4, pp. 1379–1385, 2007. DOI: 10.1016/j.matdes.2006.01.008.