International Journal of Mechatronics and Manufacturing Technology
Volume 11, Issue 1, January-June 2026
ISSN: 3139-5058 (Online)

Optimization of CNC Turning Parameters for Surface Roughness Using the Taguchi Method

Jagdish R. Wagh[1], Pallavi K. Tarte[2], Sushant V. Munde[3]

ABSTRACT

The quality of a machined surface matters to how a part performs and how long it lasts, and in turning, the cutting of a rotating workpiece on a lathe, the smoothness of the finished surface depends on the cutting parameters chosen, the speed, the feed, and the depth of cut, yet trying every combination to find the best is wasteful; the Taguchi method finds good settings with far fewer experiments. This study optimizes the turning parameters for surface roughness using the Taguchi method, identifying which parameter most affects the finish and what settings give the smoothest surface. Turning experiments were planned by a Taguchi design that varies the cutting speed, the feed rate, and the depth of cut together over a small, carefully chosen set of runs rather than every combination, the surface roughness was measured for each run, and the influence of each parameter was analysed. The feed rate was found to be by far the most influential parameter: the surface roughness rose steeply as the feed increased, because a coarser feed leaves deeper marks on the surface, whereas the cutting speed had a smaller effect, a higher speed giving a somewhat smoother surface, and the depth of cut had the least effect. The smoothest surface was therefore obtained at a low feed rate with a high cutting speed, and the Taguchi analysis identified these best settings from only a fraction of the experiments that testing all combinations would have required. The study shows that the Taguchi method efficiently identifies the cutting parameters that govern surface roughness and the settings that minimise it, and it discusses how the method guides the choice of parameters in machining.

KEYWORDS: *CNC turning, Surface roughness, Taguchi method, Cutting parameters, Feed rate, Design of experiments, Machining optimization, Process optimization, Manufacturing*

INTRODUCTION

The surface finish of a machined part is an important measure of its quality. A smoother surface resists wear and fatigue better, seals and fits more reliably, and often looks and functions better, so the roughness of a finished surface, the fineness of the marks left by machining, is frequently specified and must be achieved. In turning, the common operation of cutting a rotating workpiece on a lathe to produce cylindrical parts, the surface finish is determined largely by the cutting parameters chosen for the operation (4, 9).

Three parameters chiefly govern a turning operation: the cutting speed, how fast the workpiece surface moves past the tool; the feed rate, how far the tool advances along the workpiece for each revolution; and the depth of cut, how deeply the tool engages the material. These parameters affect not only how quickly the part is made but also the surface roughness of the result, and they interact, so that the best choice for a smooth finish is not obvious. Trying every combination of parameter values to find the best is wasteful of time, material, and machine use, especially as the number of combinations grows quickly with the number of parameters and levels (7).

The Taguchi method offers an efficient alternative. It is a method of designing experiments that varies all the parameters together over a small, carefully chosen set of runs, arranged so that the influence of each parameter can be separated out from far fewer experiments than testing every combination would need (1, 2). This paper optimizes the turning parameters for surface roughness using the Taguchi method, planning a small set of turning runs, measuring the roughness, and analysing the influence of each parameter to find which matters most and what settings give the smoothest surface. The aim is to demonstrate the efficiency of the method and to identify the parameters and settings that govern surface roughness in turning.

LITERATURE REVIEW

The prediction and optimization of surface roughness in machining have been studied extensively, and the literature, reviewed comprehensively, relates the roughness to the cutting parameters and the methods used to optimize them (5). A consistent finding across studies is that the feed rate is the dominant influence on surface roughness in turning, with the cutting speed and depth of cut playing lesser roles, a pattern explained by the geometry of how the tool marks the surface (4, 7).

THE TAGUCHI METHOD AND MACHINING OPTIMIZATION

The literature describes the Taguchi approach and its use in machining:

- The Taguchi method designs a small set of experiments that varies all parameters together, using orthogonal arrays (1, 2).
- It separates the influence of each parameter from far fewer runs than testing all combinations, and is rooted in the design of experiments (3, 6).
- Applied to turning, it has been used to find cutting parameters that minimise surface roughness (8).
- The fundamentals of machining and its recent advances are set out in the standard references (4, 9, 10).

A recurring theme is that the Taguchi method efficiently identifies the influential parameters and good settings, and that the feed rate dominates surface roughness in turning.

The Taguchi method, developed for robust quality engineering, uses specially constructed orthogonal arrays to choose a small set of experimental runs from which the effect of each parameter can be estimated, and it has been applied widely to optimize machining (1, 2, 6). Studies applying it to turning have repeatedly found the feed rate to be the most significant factor for surface roughness and identified the parameter settings that minimise it, demonstrating the method's value for machining optimization (8). The broader principles of the design of experiments underpin the approach (3), and the fundamentals of machining, cutting, and modern manufacturing, within which these results sit, are treated in the standard references (4, 7, 9, 10).

RESEARCH GAP

Although the Taguchi optimization of turning parameters is well studied, a concise demonstration that plans a small set of turning runs, measures the surface roughness, and identifies the dominant parameter and the best settings remains useful as a clear illustration of the method. There is therefore value in a study that shows how the roughness depends on the cutting parameters and how the Taguchi method efficiently finds the settings that minimise it.

OBJECTIVES

The objectives of this study are:

- To plan a small set of turning experiments using the Taguchi method, varying cutting speed, feed rate, and depth of cut.
- To measure the surface roughness for each run.
- To analyse the influence of each parameter and identify the most significant.
- To identify the settings that minimise surface roughness and discuss how the method guides the choice of parameters.

METHODOLOGY

1. Experimental Design

Turning experiments were planned by a Taguchi design, which uses an orthogonal array to choose a small set of runs that vary the cutting speed, the feed rate, and the depth of cut together over chosen levels, rather than testing every combination (1, 2). The surface roughness of the machined surface was measured for each run. The parameters and their levels are summarised in Table 1.

Table 1: Turning parameters and their levels

Parameter	Levels considered
Cutting speed	Low, medium, high (m/min)
Feed rate	Low to high (mm/rev)
Depth of cut	Low, medium, high (mm)
Response	Surface roughness of machined surface

2. Analysis

From the measured roughness across the planned runs, the influence of each parameter was analysed by comparing how the roughness changed as each parameter varied, which the Taguchi design allows to be separated despite the small number of runs (8). The parameters were ranked by their influence, and the combination of settings giving the lowest surface roughness was identified, so that both the dominant parameter and the best settings could be determined.

RESULTS AND FINDINGS

The feed rate was found to be by far the most influential parameter on surface roughness, as shown in Figure 1, which plots the surface roughness against the feed rate at three cutting speeds. The roughness rose steeply as the feed rate increased, more than doubling across the range, because a coarser feed advances the tool further per revolution and leaves deeper, more widely spaced marks on the surface (5). This steep dependence on feed dominated the results.

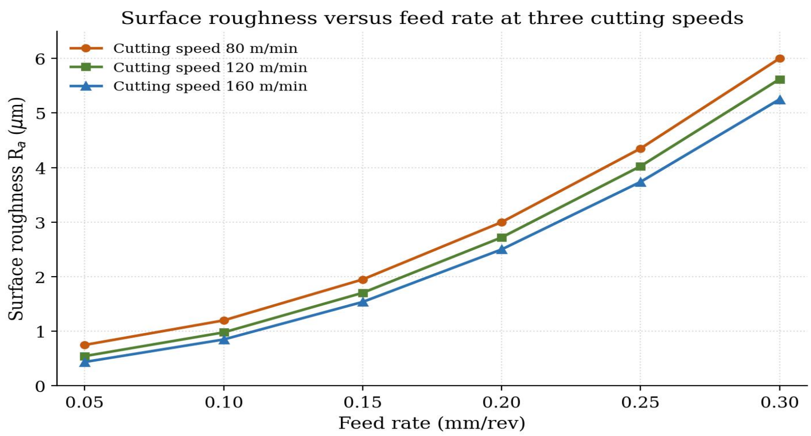

Figure 1: Surface roughness versus feed rate at three cutting speeds

The cutting speed had a smaller effect: at a given feed, a higher cutting speed gave a somewhat smoother surface, the curves for the higher speeds lying a little below those for the lower, an effect attributed to more favourable cutting at higher speeds (7). The depth of cut had the least effect of the three. The smoothest surface was therefore obtained at a low feed rate combined with a high cutting speed, and the Taguchi analysis identified these settings from only a fraction of the runs that testing all combinations would have required (1). The ranking of the parameters is summarised in Table 2.

Table 2: Influence of the parameters on surface roughness

Parameter	Influence	Best setting for low roughness
Feed rate	Greatest	Low feed
Cutting speed	Moderate	High speed
Depth of cut	Least	Less critical
Method efficiency	Few runs vs all combinations	—

DISCUSSION

The results show that the Taguchi method efficiently identifies the cutting parameters that govern surface roughness and the settings that minimise it. The clearest finding, that the feed rate dominates the surface roughness, agrees with the established understanding of turning and has a simple physical explanation: the marks left on a turned surface are spaced by the feed, so a larger feed leaves coarser, deeper marks and a rougher surface, while a smaller feed leaves finer marks and a smoother surface (5, 7). The cutting speed matters less, affecting the finish chiefly through the quality of cutting, and the depth of cut least of all, so attention to the feed yields the greatest improvement in finish.

The efficiency of the Taguchi method is its central practical value, and it follows from the design of the experiments. Testing every combination of three parameters at several levels each would require many runs, each consuming time, material, and machine use, whereas the Taguchi orthogonal array chooses a small subset of runs arranged so that the effect of each parameter can still be separated out, giving the same essential information, which parameter matters and what setting is best, from far fewer experiments (1, 2). This makes the method attractive in practice, where experiments are costly, and it is rooted in the wider statistical theory of the design of experiments (3, 6).

The practical significance is that a machinist or process engineer can use the Taguchi method to set the cutting parameters of a turning operation for a required surface finish quickly and with confidence, knowing which parameter to adjust for the greatest effect. The result, that a low feed gives the smoothest surface, must be balanced against productivity, since a lower feed also means slower machining, so the parameters are chosen to meet the roughness requirement while keeping the operation as productive as possible, a balance the analysis informs (8, 9). The practical conclusion is that the Taguchi method is an efficient and reliable way to optimize turning parameters for surface roughness, the main caveats being that the findings depend on the workpiece material, the tool, and the machine, and that the method identifies good settings among those tested rather than a guaranteed global optimum.

LIMITATIONS

The following limitations apply to this study:

- The findings depend on the workpiece material, the cutting tool, and the machine, which vary.

- The Taguchi method identifies good settings among those tested rather than a guaranteed global optimum.
- Surface roughness was the response considered; tool wear, cutting forces, and productivity were not optimized jointly.
- Interactions between parameters were not examined in detail.

FUTURE SCOPE

Future work could extend the present study as follows:

- Joint optimization of surface roughness with productivity, tool wear, and cutting forces.
- Examination of interactions between the cutting parameters.
- Application to different workpiece materials, tools, and machining operations.
- Comparison of the Taguchi method with other optimization approaches.
- Inclusion of further parameters, such as tool nose radius and coolant, in the design.

CONCLUSION

The turning parameters for surface roughness were optimized using the Taguchi method, by planning a small set of runs varying the cutting speed, feed rate, and depth of cut, measuring the roughness, and analysing the influence of each parameter. The feed rate was by far the most influential, the roughness rising steeply with feed because a coarser feed leaves deeper marks, while the cutting speed had a smaller effect, a higher speed smoothing the surface, and the depth of cut the least; the smoothest surface was obtained at a low feed with a high cutting speed, identified from a fraction of the runs that testing all combinations would need. The study shows that the Taguchi method efficiently identifies the cutting parameters that govern surface roughness and the settings that minimise it, balanced against productivity, with the caveats that the findings depend on the material, tool, and machine and that the method finds good settings among those tested rather than a guaranteed global optimum.

REFERENCES

1. Taguchi, G., Chowdhury, S., & Wu, Y. (2005). *Taguchi's quality engineering handbook*. John Wiley & Sons.
2. Phadke, M. S. (1989). *Quality engineering using robust design*. Prentice Hall.
3. Montgomery, D. C. (2017). *Design and analysis of experiments* (9th ed.). John Wiley & Sons.

4. Boothroyd, G., & Knight, W. A. (2006). *Fundamentals of machining and machine tools* (3rd ed.). CRC Press.
5. Benardos, P. G., & Vosniakos, G. C. (2003). Predicting surface roughness in machining: A review. *International Journal of Machine Tools and Manufacture*, 43(8),
833–844.
6. Ross, P. J. (1996). *Taguchi techniques for quality engineering* (2nd ed.). McGraw-Hill.
7. Trent, E. M., & Wright, P. K. (2000). *Metal cutting* (4th ed.). Butterworth-Heinemann.
8. Yang, W. H., & Tarng, Y. S. (1998). Design optimization of cutting parameters for turning operations based on the Taguchi method. *Journal of Materials Processing Technology*, 84(1–3), 122–129.
9. Groover, M. P. (2010). *Fundamentals of modern manufacturing: Materials, processes, and systems* (4th ed.). John Wiley & Sons.
10. Davim, J. P. (Ed.). (2008). *Machining: Fundamentals and recent advances*. Springer.

***Author for Correspondence**
Jagdish R. Wagh
E-mail: jagdishwagh7676@gmail.com

[1]Associate Professor, Department of Manufacturing Engineering, RMS Institute of Engineering, Nashik, Maharashtra
[2]Assistant Professor, Department of Mechanical Engineering, RMS Institute of Engineering, Nashik, Maharashtra
[3]Research Scholar, Department of Production Engineering, Datta Meghe Institute of Engineering, Dhule, Maharashtra

Received Date: May 23, 2026
Accepted Date: June 02, 2026
Published Date: June 12, 2026

Citation: Jagdish R. Wagh, Pallavi K. Tarte, Sushant V. Munde. Optimization of CNC Turning Parameters for Surface Roughness Using the Taguchi Method. International Journal of Mechatronics and Manufacturing Technology. 2026; 11(1): 17-24p.