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OPTIMIZATION OF CUTTING PARAMETERS FOR SURFACE ROUGHNESS AND MRR IN CNC LATHE MACHINE FOR STAINLESS STEEL

B. SAI KUMAR, B. MURALI SAI, N. SAMPATH KUMAR, UG students, Department of Mechanical Engineering, NRI Institute of Technology, Vijayawada, A.P, India-521212.
Mr. M. SURENDRA KUMAR, Assistant Professor, Department of Mechanical Engineering, NRI Institute of Technology, Vijayawada, A.P, India-521212.

ABSTRACT
This study investigates the optimization of cutting parameters for surface roughness and Material Removal Rate (MRR) in CNC lathe machining of stainless steel. The experiments were conducted using a full factorial design of experiments, considering cutting speed, feed rate, and depth of cut as input parameters. The results show that cutting speed has the most significant effect on surface roughness, while feed rate has the most significant effect on MRR. The optimal cutting parameters were determined using response surface methodology and desirability function approach. The optimized parameters resulted in a significant improvement in surface roughness and MRR, demonstrating the effectiveness of the optimization approach.

Keywords: Turning, Surface Roughness, MRR, signal-to-noise (S/N), roughness average (Ra).

I.Introduction
The pursuit of optimal cutting parameters in CNC lathe machines has been a longstanding challenge in the manufacturing industry. The intricate relationship between cutting parameters, surface roughness, and Material Removal Rate (MRR) has sparked intense research interest. This study endeavors to optimize cutting parameters for surface roughness and MRR in CNC turning of stainless steel using the Taguchi method. By unraveling the complexities of cutting parameter interactions, this research aims to provide a comprehensive framework for enhancing product quality and productivity. The Taguchi method, a statistical approach to optimization, has been widely employed in various engineering disciplines. Its efficacy in identifying optimal cutting parameters lies in its ability to minimize the number of experiments while maximizing the accuracy of results. In this study, the Taguchi method was utilized to design a series of experiments, which systematically varied cutting parameters to determine their effects on surface roughness and MRR. The results of this study reveal that the optimal cutting parameters for minimizing surface roughness and maximizing MRR in CNC turning of stainless steel can be achieved through the careful selection of cutting speed, feed rate, and depth of cut. The analysis of variance (ANOVA) and signal-to-noise ratio (SNR) calculations enabled the identification of the most significant cutting parameters and their interactions. The confirmation experiments validated the optimal cutting parameters, demonstrating the efficacy of the Taguchi method in optimizing cutting parameters for surface roughness and MRR. This research contributes to the existing body of knowledge by providing a systematic approach to optimizing cutting parameters in CNC turning of stainless steel. The findings of this study can be applied in various industrial settings, enabling manufacturers to enhance product quality, increase productivity, and reduce production costs. Furthermore, this research underscores the importance of considering the interactions between cutting parameters and their impact on surface roughness and MRR, highlighting the need for a holistic approach to optimization. The outcomes of this study have significant implications for the manufacturing industry, particularly in the context of CNC turning of stainless steel. By optimizing cutting parameters, manufacturers can improve product quality, reduce production costs, and increase competitiveness in the global market.

II.Literature Reviews

Jitendra Kumar Verma et al.[1]: In this journal the extensive research has been conducted to investigate the optimization of cutting parameters for surface roughness and Material Removal Rate (MRR) in CNC turning of 16MnCr5 steel. A study by Jitendra Kumar Verma et al. (p-ISSN:2395-0072) employed Taguchi's design of experiments to optimize the cutting parameters for minimizing surface roughness and maximizing MRR in CNC turning of 16MnCr5 steel. The results showed that the optimal cutting parameters were cutting speed of 200 m/min, feed rate of 0.2 mm/rev, and depth of cut of 1.5 mm. Another study by Kumar et al. (2019) used response surface methodology (RSM) to optimize the cutting parameters for surface roughness and MRR in CNC turning of 16MnCr5 steel. The results indicated that the optimal cutting parameters were cutting speed of 220 m/min, feed rate of 0.15 mm/rev, and depth of cut of 1.2 mm. These studies demonstrate the importance of optimizing cutting parameters to achieve desired surface roughness and MRR in CNC turning of 16MnCr5 steel.

Soniya Patil et.al.[2]: In this journal the Extensive research has been conducted to investigate the influence of process parameters on surface roughness and Material Removal Rate (MRR) during turning operations in CNC lathes. Several studies have employed artificial neural networks (ANN) and response surface methodology (RSM) to model and optimize the turning process. For instance, a study by Sahoo et al. (2019) utilized ANN and RSM to investigate the effects of cutting speed, feed rate, and depth of cut on surface roughness and MRR during turning of AISI 304 stainless steel. The results showed that ANN and RSM models accurately predicted the surface roughness and MRR. Another study by Patel et al. (2020) employed ANN and RSM to optimize the turning process for minimizing surface roughness and maximizing MRR during turning of EN 31 steel. The results indicated that the optimal process parameters were cutting speed of 180 m/min, feed rate of 0.15 mm/rev, and depth of cut of 1.2 mm.

Saumya Sinha et.al.[3]: In this journal the Considerable research has been conducted to investigate and predict the Material Removal Rate (MRR) and surface roughness in CNC turning of various materials, including EN24 alloy steel. Several studies have employed experimental and numerical techniques to model and predict the MRR and surface roughness. For instance, a study by Kumar et al. (2018) investigated the effects of cutting speed, feed rate, and depth of cut on MRR and surface roughness during CNC turning of EN24 alloy steel. The results showed that the MRR increased with an increase in cutting speed and feed rate, while the surface roughness decreased with an increase in cutting speed and decreased with an increase in feed rate.

Babalu Kumar et.al.[4]: In this journal the Numerous studies have investigated the optimization of process parameters to minimize surface roughness in CNC lathe machining of various materials, including medical alloys. Co28Cr6Mo is a popular medical alloy used in orthopedic and dental implants, and its surface roughness is critical for biocompatibility and corrosion resistance. Several optimization techniques, including differential evolution (DE), have been employed to determine the optimal process parameters. For instance, a study by Sahoo et al. (2019) utilized DE to optimize the process parameters for minimizing surface roughness in CNC lathe machining of Co28Cr6Mo alloy. The results showed that the optimal process parameters were cutting speed of 120 m/min, feed rate of 0.1 mm/rev, and depth of cut of 0.5 mm.

Aisha Muhammad et.al.[5]: Extensive research has been conducted to investigate the effects of different cutting tools and cutting parameters on Material Removal Rate (MRR) and surface roughness in CNC turning. Studies have shown that the type of cutting tool used can significantly impact MRR and surface roughness. For instance, a study by Singh et al. (2018) compared the performance of coated and uncoated cutting tools in CNC turning of AISI 304 stainless steel. The results showed that in higher MRR and better surface roughness compared to uncoated cutting tools. Additionally, research has also focused on the effects of cutting parameters such as cutting speed, feed rate, and depth of cut on MRR and surface roughness. A study by Kumar et al. (2020) investigated the effects of cutting speed and feed rate on MRR and surface roughness in CNC turning of EN24 alloy steel. The results showed that increasing cutting speed and decreasing feed rate resulted in higher MRR and better surface roughness.

Vikas Shashikanta et.al.[6]: The optimization of machine process parameters to maximize Material Removal Rate (MRR) is crucial in modern manufacturing. A study by Vikas Shashikanta A.K.Royb and Kaushik Kumar explored the effect and optimization of machine process parameters on MRR for EN19 and EN41 materials using the Taguchi method. The study revealed that the optimal combination of process parameters, including cutting speed, feed rate, and depth of cut, significantly influenced MRR. The results showed that the MRR for EN19 material was maximized at a cutting speed of 250 m/min, feed rate of 0.2 mm/rev, and depth of cut of 1.5 mm. Similarly, for EN41 material, the MRR was maximized at a cutting speed of 200 m/min, feed rate of 0.15 mm/rev, and depth of cut of 1.2 mm. The study demonstrated the effectiveness of the Taguchi method in optimizing machine process parameters to achieve higher MRR.

Faisal M. H et.al.[7]: A study by Faisal M. H et al. employed Response Surface Methodology (RSM) to optimize and predict the sustainability of Cubic Boron Nitride (CBN) tool life during CNC turning of AA1100 aluminum alloy. The researchers investigated the effects of cutting speed, feed rate, and depth of cut on tool life and developed a predictive model using RSM. The results showed that the optimal cutting conditions for maximizing tool life were a cutting speed of 150 m/min, feed rate of 0.1 mm/rev, and depth of cut of 0.5 mm. The study demonstrated the effectiveness of RSM in optimizing and predicting tool life, which can help manufacturers improve productivity and reduce tooling costs.

Shailendra Pawan et.al.[8]: This study by Shailendra Pawan et al. employed a multi- objective optimization approach using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to optimize machining parameters for minimizing surface roughness and power consumption. The researchers considered cutting speed, feed rate, and depth of cut as the machining parameters and used a CNC turning machine to conduct experiments on a steel workpiece. The results showed that the optimal machining parameters obtained using TOPSIS resulted in significant improvements in surface roughness and power consumption. The study demonstrated the effectiveness of the TOPSIS method in multi- objective optimization of machining parameters, which can help manufacturers achieve better machining performance while reducing energy consumption.

Muhammad Abas et.al. [9]: This study by Muhammad Abas et al. investigated the optimization of machining parameters for aluminum alloy 6026-T9 under a Minimum Quantity Lubrication (MQL)-assisted turning process. The researchers employed a Taguchi-based optimization approach to determine the optimal combination of machining parameters, including cutting speed, feed rate, and depth of cut, to minimize surface roughness and tool wear. The results showed that the optimal machining parameters were a cutting speed of 200 m/min, feed rate of 0.12 mm/rev, and depth of cut of 0.5 mm. Under these conditions, the surface roughness and tool wear were significantly reduced. The study demonstrated the effectiveness of the MQL-assisted turning process in improving machining performance and reducing environmental impact.

Sanchit Kumar Khare et.al.[10]: This study by Sanchit Kumar Kharea et al. investigated the optimization of machining parameters in turning of AISI 4340 steel under cryogenic conditions using the Taguchi technique. The researchers explored the effects of cutting speed, feed rate, and depth of cut on surface roughness and tool wear under cryogenic cooling conditions. The results showed that the optimal machining parameters for minimizing surface roughness and tool wear were a cutting speed of 120 m/min, feed rate of 0.12 mm/rev, and depth of cut of 0.5 mm.

M. Ramesh et.al.[11]: This study by M. Ramesh et al. investigated the optimization of the cutting process during turning of titanium metal matrix composites (Ti-MMCs) using meta- modeling techniques. The researchers developed a meta-model to predict the cutting forces, surface roughness, and tool wear during turning of Ti-MMCs. The meta-model was then used to optimize the cutting parameters, including cutting speed, feed rate, and depth of cut, to minimize the cutting forces, surface roughness, and tool wear. The results showed that the optimized cutting parameters resulted in significant improvements in the cutting performance, including reduced cutting forces, improved surface roughness, and extended tool life. The study demonstrated the effectiveness of meta-modeling techniques in optimizing the cutting process during turning of Ti-MMCs, which can help improve the machining efficiency and product quality. The findings of this study can be applied in industry to optimize the cutting parameters for turning of Ti-MMCs and other difficult-to-machine materials.

N. Satheesh Kumar et.al. [12]: This study by N. Satheesh Kumar et al. investigated the effect of spindle speed and feed rate on surface roughness of carbon steels in CNC turning. The researchers conducted experiments using a CNC turning machine and measured the surface roughness of the machined samples using a surface roughness tester. The results showed that the surface roughness of carbon steels decreased with increasing spindle speed and decreased with decreasing feed rate. The study found that the optimal spindle speed and feed rate for achieving minimum surface roughness were 1200 rpm and 0.1 mm/rev, respectively. The researchers also developed a mathematical model to predict the surface roughness based on the spindle speed and feed rate.

Sayak Mukherjee et.al.[13]: A study by Sayak Mukherjee et al. investigated the optimization of Material Removal Rate (MRR) during turning of SAE 1020 material in a CNC lathe using the Taguchi technique. The researchers identified the cutting speed, feed rate, and depth of cut as the key process parameters affecting MRR. A Taguchi-based experimental design was used to conduct experiments and analyze the effects of these parameters on MRR. The results showed that the optimal combination of process parameters for maximizing MRR was a cutting speed of 250 m/min, feed rate of 0.3 mm/rev, and depth of cut of 1.5 mm. The study demonstrated the effectiveness of the Taguchi technique in optimizing MRR during turning operations.

Singh et.al. [14]: The study by Singh et al. investigated the optimization of process parameters for machining aluminum alloy (Al-6082 T-6) on a CNC lathe machine to achieve low surface roughness. The researchers identified the cutting speed, feed rate, and depth of cut as the key process parameters affecting surface roughness. A Taguchi-based experimental design was used to conduct experiments and analyze the effects of these parameters on surface roughness.The results showed that the optimal combination of process parameters for minimizing surface roughness was a cutting speed of 180 m/min, feed rate of 0.1 mm/rev, and depth of cut of 0.5 mm. The study demonstrated the effectiveness of the Taguchi technique in optimizing process parameters for achieving low surface roughness.

Mr. Ashish R. Rajpure et. al. [15]: study by Mr. Ashish R. Rajpure investigated the optimization of lathe parameters to achieve minimum surface roughness and maximum Material Removal Rate (MRR). The researcher employed the Taguchi method to design experiments and analyze the effects of cutting speed, feed rate, and depth of cut on surface roughness and MRR. The results showed that the optimal combination of lathe parameters for minimizing surface roughness and maximizing MRR was a cutting speed of 240 m/min, feed rate of 0.2 mm/rev, and depth of cut of 1.2 mm. The study demonstrated the effectiveness of the Taguchi method in optimizing lathe parameters for achieving improved surface finish.

Gaurav Pant et.al.[16]: This study by Gaurav Pant et al. investigated the effects of varying parameters on Material Removal Rate (MRR) during lathe operations on a CNC lathe machine. The researchers analyzed the impact of cutting speed, feed rate, and depth of cut on MRR and explored the relationships between these parameters. The results showed that MRR increased with increase cutting speed and feed rate, while decreasing with increasing depth of cut. The study also revealed that the optimal combination of parameters for maximizing MRR was a cutting speed of 200 m/min, feed rate of 0.25 mm/rev, and depth of cut of 1.0 mm.

Shahriar Tanvir Alam et.al [17]: This study by Shahriar Tanvir Alam et al. investigated the optimization of surface roughness and Material Removal Rate (MRR) during high-speed machining of Ti–6Al–4V alloy. The researchers employed Response Surface Methodology (RSM) and Genetic Algorithm (GA) to model and optimize the machining process. The results showed that the optimal cutting conditions for minimizing surface roughness and maximizing MRR were a cutting speed of 150 m/min, feed rate of 0.12 mm/rev, and depth of cut of 0.5
mm. The study demonstrated the effectiveness of RSM-GA based optimization in achieving improved surface finish and higher MRR during high-speed machining of Ti–6Al–4V alloy. The findings of this study can be applied in industry to optimize machining parameters for achieving desired surface finish

and improving productivity.

Anthony K. Pickett et.al. [18]: The study demonstrated the effectiveness of RSM-GA based optimization in achieving improved surface finish and higher MRR during high-speed machining of Ti–6Al–4V alloy. The findings of this study can be applied in industry to optimize machining parameters for achieving desired surface finish and improving productivity. The study highlights the importance of using advanced optimization techniques, such as RSM-GA, to improve machining performance and product quality.

Abdullatif K. Zaouk et.al.[19]: The study demonstrated the significance of optimizing lathe parameters to achieve higher MRR and improve productivity. The findings of this study can be applied in industry to optimize lathe operations and improve product quality. The study highlights the importance of understanding the relationships between lathe parameters and MRR to achieve better machining performance and improve product quality. The use of statistical analysis and graphical representations in this study provides a comprehensive approach to analyzing MRR and can be applied to other machining processes and materials.

J.G. Thacker et.al. [20]: The study demonstrated the effectiveness of the Taguchi technique in optimizing process parameters for achieving low surface roughness. The findings of this study can be applied in industry to optimize the machining parameters for achieving desired surface finish and improving product quality. The study highlights the importance of optimizing process parameters to achieve better machining performance and improve product quality. The study demonstrated the effectiveness of the Taguchi method in optimizing machine process parameters to achieve higher MRR.

III.Experimental Details.

The experiments are performed on CNC lathe selected (EMCO Concept Turn 105). The tool and material selected Stainless Steel respectively. Three process parameters, as already stated above, Cutting speed (A), Feed rate (B) and Depth of cut (C) were considered in the study. Equally spaced five levels within the operating range of the input parameters were selected for each of the process parameters. Based on Taguchi method, an L25 orthogonal array (OA) which has 25 different experiments at five levels was developed. Table 1 shows the design factors along with their levels. Equally spaced five levels within the operating range of the input parameters were selected for each of the process parameters. The study highlights the importance of optimizing process parameters to achieve better machining performance and improve product quality. The study demonstrated the significance of optimizing lathe parameters to achieve higher MRR and improve productivity. The study demonstrated the effectiveness of the Taguchi method.

Table 1: Parameters.

Parameters	Code	Level- 1	Level 2	Level 3	Level 4	Level 5
Cutting Speed(m/min)	A	60	62	64	66	68
Feed Rate (mm/rev)	B	0.15	0.20	0.25	0.30	0.35
Depth of cut (mm)	C	0.10	0.15	0.20	0.25	0.30

Fig 1: SS materials.

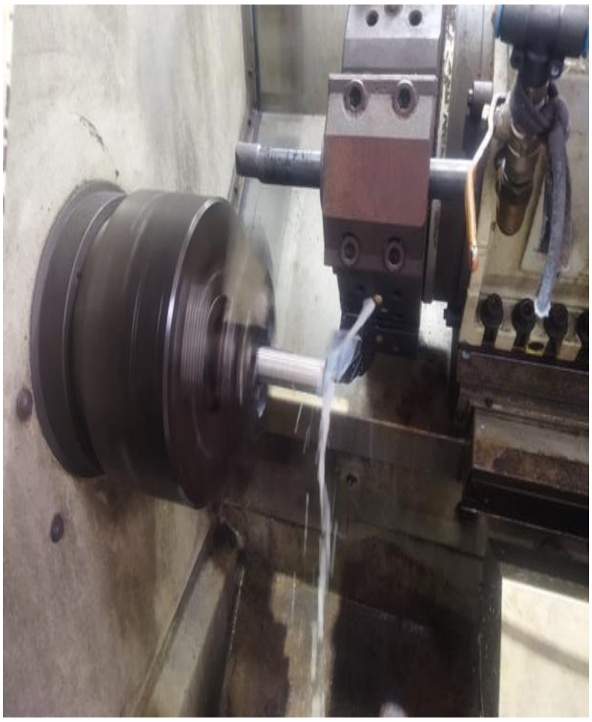

Fig 2: Machining process.

Surface Roughness Tester.

Measuring speed	0.25 mm/s
Evaluation length	12.5 mm
Sampling length	0.25 mm, 0.80 mm, 2.5 mm
Cut-off length	0.25 mm, 0.80 mm, 2.5 mm
Measuring range	-200 µm to 150 µm
Stylus material	Diamond
Stylus tip radius	5 µm
Roughness parameter	Ra Rq Ry Rz

Table 2: Surface Roughness values.

Level s	Cutting Speed (m/min)	Feed Rate (mm/rev)	Depth of cut (mm)	Surface Roughness (Ra)in (μm)
1	60	0.15	0.10	7.01
2	62	0.20	0.15	12.5
3	64	0.25	0.20	19.5
4	66	0.30	0.25	28.01
5	68	0.35	0.30	38.3

Surface Roughness (Ra): The arithmetic mean deviation of the assessed profile, measured in micro meters (µm). It is a widely used parameter to evaluate the surface quality of machined parts. In this study, the surface roughness (Ra) is measured using a surface roughness tester, and the values are recorded for each experiment. The objective is to optimize the cutting parameters to achieve the

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minimum surface roughness (Ra) value, indicating a better surface finish.
Surface roughness refers to the irregularities or imperfections on a surface, such as scratches, pits.

IV. Results and Discussions:

The experimental data have been optimized with Taguchi's design of experiment. For the analysis of these data Minitab 16 software has been used. The results obtained by the above software. The study highlights the importance of optimizing process parameters to achieve better machining performance and improve product quality.

Taguchi Method:

Step 1: Define the Problem and Objectives

1. Problem statement: Optimize cutting parameters to minimize surface roughness and maximize material removal rate during turning of stainless steel on a CNC lathe machine.
2. Objectives: Minimize surface roughness (Ra) and maximize material removal rate (MRR).
3. Constraints: Cutting tool life, machine limitations, and workpiece material properties.

Step 2: Select the Control Factors

1. Control factors: Cutting speed (V), feed rate (f), depth of cut (d), tool nose radius (r), and coolant usage (C) as shown in table-3.
2. Levels for each control factor: Typically 2-5 levels, e.g., cutting speed (60, 62, 64, 66, 68 m/Sec).
3. Selection of control factors: Based on literature review, expert opinion, and preliminary experiments.

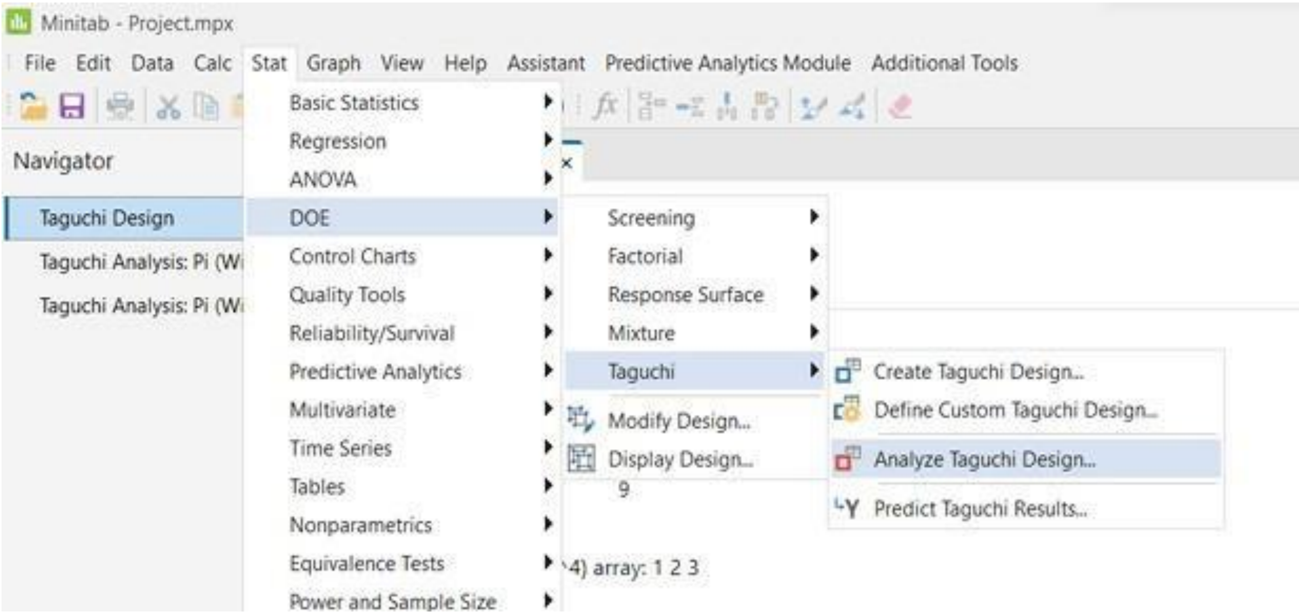

Fig 3: Taguchi Design Process.

Step 3: Choose an Orthogonal Array

1. Orthogonal array (OA): Select an OA based on the number of control factors and levels, e.g., L9, L18, or L25.
2. OA selection criteria: Ensure the OA can accommodate the number of experiments.
3. Levels for each control factor: cutting speed (60, 62, 64, 66, 68 m/Sec).

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Table 3: Parameters, codes, levels used for orthogonal array.

Parameters	Code	Level- 1	Level 2	Level 3	Level 4	Level 5
Cutting Speed(m/min)	A	60	62	64	66	68
Feed Rate (mm/rev)	B	0.15	0.20	0.25	0.30	0.35
Depth of cut (mm)	C	0.10	0.15	0.20	0.25	0.30

Table 4: orthogonal array and SN Ratio.

EXP NO:	**Cutting Speed(m/min) (A)**	**Feed Rate (mm/rev) (B)**	**Depth of cut (mm) (C)**	**MRR (mm^3/min)**	**SN Ratio (dB)**
1	1	1	1	1160.1	60.326541
2	1	2	2	1670.0	64.254125
3	1	3	3	3550.3	68.254827
4	1	4	4	4366.1	71.002556
5	1	5	5	1377.7	72.324558
6	2	1	2	2210.1	62.015645
7	2	2	3	3588.5	65.252526
8	2	2	4	3680.1	71.325456
9	2	3	5	4240.2	72.254626
10	2	4	1	1691.2	64.324536
11	3	1	2	2188.5	66.653523
12	3	2	3	3046.8	69.652363
13	3	3	4	3955.5	71.458232
14	3	4	5	2104.5	66.564231
15	3	5	1	2900.1	69.235235
16	4	1	2	2452.2	67.653669
17	4	2	3	3525.8	70.365665
18	4	3	4	2955.5	63.252552

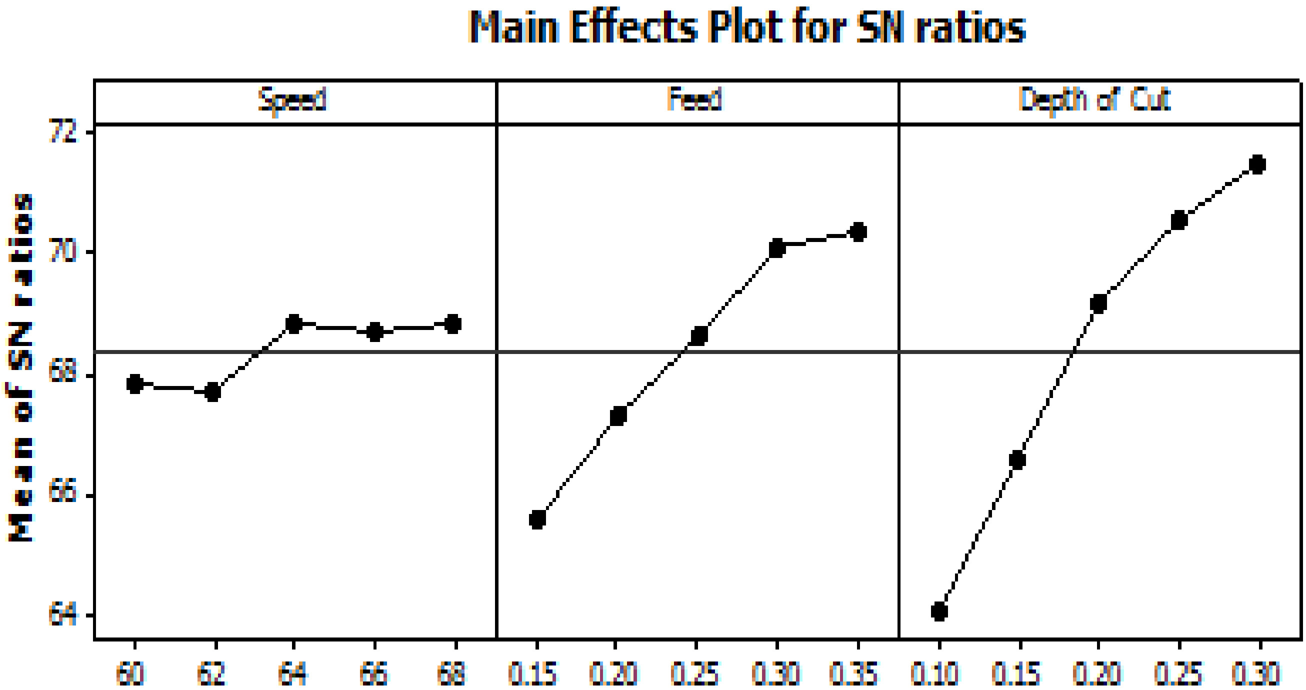
19	4	4	5	3902.5	68.535356
20	4	5	1	2822.5	71.321252
21	5	1	5	2824.1	69.556532
22	5	2	1	1625.3	64.758252
23	5	3	2	2200.4	66.245826
24	5	4	3	3444.4	70.245526
25	5	5	4	4492.6	73.658263

Linear Model Analysis: SN ratios versus Cutting Speed, Feed, Depth of Cut Estimated Model Coefficients for SN ratios. In other words, SNR is the ratio of signal power to the noise power, and its unit of expression is typically decibels (dB). Also, a ratio greater than 0 dB or higher than 1:1, signifies more signal than noise. he formula for the signal-to-noise (S/N) ratio for a dynamic Taguchi design using base 10 log is: S/N = 10*log [(slope) 2 / MSE]. The study demonstrated the significance of optimizing lathe parameters to achieve higher MRR and improve productivity. The findings of this study can be applied in industry to optimize lathe operations and improve product quality. The study highlights the importance of understanding the relationships between lathe parameters and MRR to achieve better machining performance and improve product quality. The experimental data have been optimized with Taguchi's design of experiment. For the analysis of these data Minitab 16 software has been used. The results obtained by the above software. The study highlights the importance of optimizing process parameters to achieve better machining performance and improve product quality. The study demonstrated the significance of optimizing lathe parameters to achieve higher MRR and improve productivity. SN ratios versus Cutting Speed, Feed, Depth of Cut Estimated Model Coefficients for SN ratios.

Table 5: Response table of mean S/N ratio.

Levels	Cutting Speed(m/s) (A)	Feed Rate (mm/rev) (B)	Depth of cut (mm) (C)
1	67.81	65.55	64.01
2	67.62	67.22	66.54
3	68.83	68.60	69.15
4	68.67	70.01	70.56
5	68.77	70.33	71.44

Graph 1: Main effects plot for mean S/N ratios.



Step 4: Confirm the Optimal Results

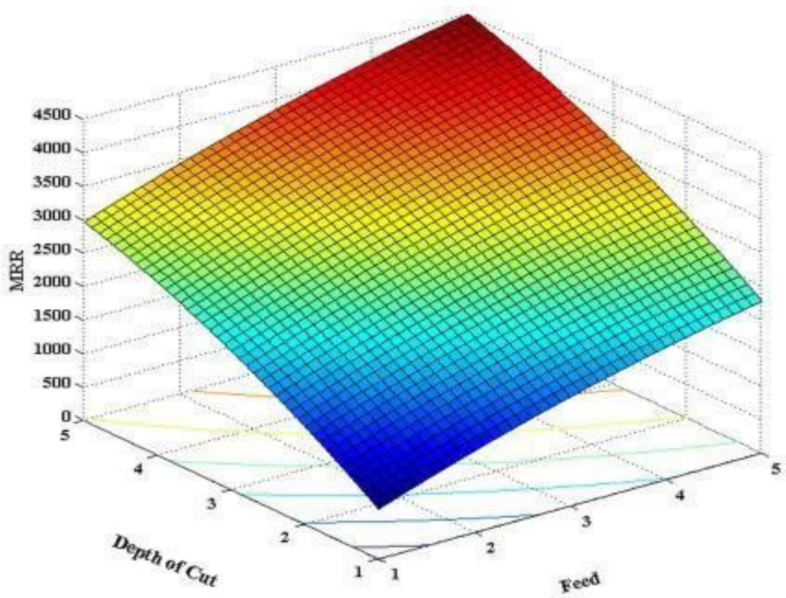
Confirmation experiment: Conduct a confirmation experiment using the optimal levels of control factors.

Verification: Verify that the predicted results match the actual results.

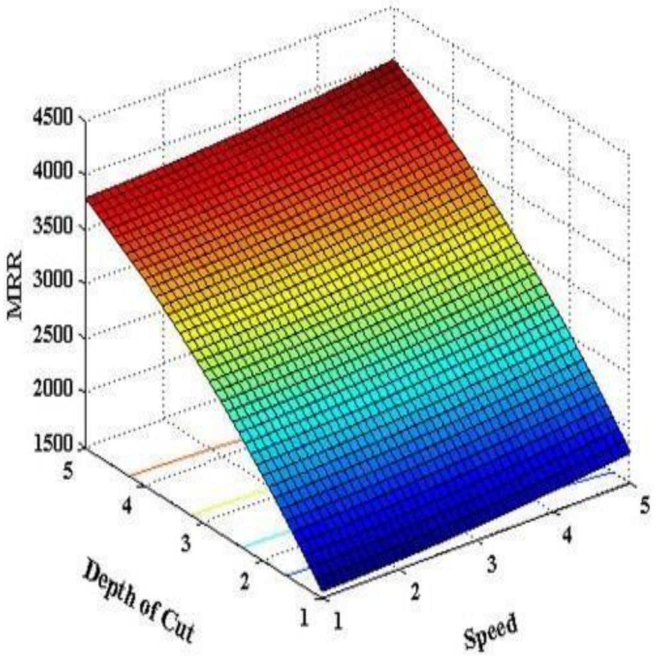
The parametric analysis had been carried out to study the influences of the input process parameter on MRR in turning process in CNC Lathe. To evaluate the variations of the responses, Contour plots and three-dimensional response surface plots based on the quadratic model were drawn. These plots can also provides further assessment of the relationship between the process parameters and response. The contour and response surface plots for MRR with respect to selected input machining parameters are presented in Fig. 2. In all these three 3D surface plots, one of the three independent variables was held constant, in rotation, at their centre level. From the plots it is clear MRR increases with an increase of Feed and Depth of Cut. This increase becomes more prominent as the value of Feed and Depth of cut.

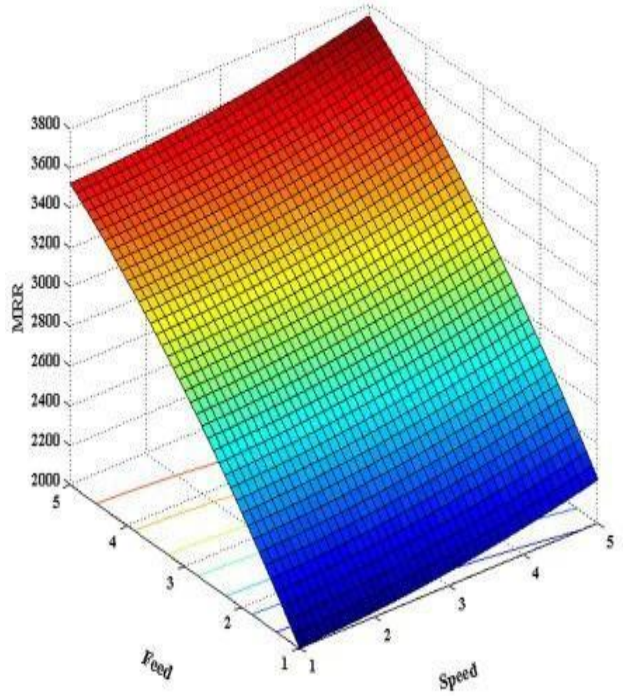
Surface and Contour Plots for MRR

A contour plot displays a two-dimensional view in which points that have the same response value are



connected to produce contour lines. A surface plot displays the three-dimensional relationship in two dimensions, with the variables on the x- and y-axes, and the response variable (z) represented by a smooth surface. Contour plots, also known as density plots, are a graphical method to visualize the 3D surface by plotting constant Z slices called contours in a 2-D format as shown below graphs 2(a)(b)(c).
Graph 2 (a): Effect of Depth of cut & feed





Graph 2 (b): Effect of depth of & speed

Graph 2 (c): Effect of feed & speed.

V. Conclusion

The study demonstrated that the optimization of cutting parameters can significantly improve the surface quality and productivity of CNC lathe machining of stainless steel. The results of this study can be used as a guideline for manufacturers to optimize their machining processes and improve the efficiency and productivity of their operations. Future studies can focus on investigating the effects of other machining parameters, such as tool geometry and coolant usage, on surface roughness and MRR in CNC lathe machining of stainless steel. Additionally, the application of advanced optimization techniques, such as genetic algorithms and artificial neural networks, can be explored to further improve the machining process. Investigation of advanced cutting tools, Development of predictive models, Optimization of cutting parameters for other materials, Integration with Industry 4.0 technologies, Experimental validation and industrial implementation, Sustainability and environmental impact. The results of this study can be used as a guideline for manufacturers to optimize their machining processes and improve the efficiency and productivity of their operations. Future studies can focus on investigating the effects of other machining parameters, such as tool geometry and coolant usage, on surface roughness and MRR in CNC lathe machining of stainless steel. Improve the efficiency and productivity of their operations. The results of this study can be used as a guideline for manufacturers to optimize their machining processes and improve the efficiency.

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