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OPTIMIZATION OF CUTTING PARAMETERS FOR SURFACE ROUGHNESS AND MRR IN CNC LATHE MACHINE FOR BRASS ALLOY

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ABSTRACT
This study investigates the optimization of cutting parameters for surface roughness and Material Removal Rate (MRR) in CNC lathe machining of brass alloy. 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 MRR, demonstrating the effectiveness of the optimization approach.
Keywords: Turning, Surface Roughness, MRR, Depth of cut, Feed Rate, cutting Parameters.

I. Introduction
A CNC lathe is a sophisticated Machine Tool designed for precision CNC Turning and manufacturing through computer numerical control(CNC). It's an embodiment of technological evolution, marrying the age-old principles of a lathe machine with advanced computer programming to achieve unprecedented accuracy and efficiency in machining. A CNC lathe machine is a computer-controlled machine tool used to shape materials such as metal or wood. It utilizes Computer Numerical Control (CNC) technology to automate machining, allowing for precise and efficient production. CNC lathe machines are crucial in various industries, including manufacturing, automotive, aerospace, and medical. They offer unparalleled precision and accuracy, enabling the creation of complex parts with ease. These machines also enhance productivity and efficiency by reducing manual labor and minimizing errors.
A CNC lathe machine is a sophisticated tool used for precision CNC turning and manufacturing through Computer Numerical Control (CNC). It automates machining, allowing for precise and efficient production by rotating the workpiece while a cutting tool removes material to create the desired shape or design. Surface roughness is a measure of the texture of a surface, and it plays a significant role in determining the functional performance of a machined component. A high surface roughness can lead to increased friction, wear, and tear, which can result in reduced component life and increased maintenance costs. On the other hand, MRR is a measure of the rate at which material is removed from the workpiece, and it directly affects the productivity and efficiency of the machining process. The optimization of cutting parameters, such as cutting speed, feed rate, and depth of cut, is essential to achieve the desired surface roughness and MRR. However, the optimization process is complex and involves multiple variables, making it challenging to determine the optimal cutting parameters.
A CNC lathe is a sophisticated machine tool designed for precision CNC turning and manufacturing through computer numerical control (CNC) . It's an embodiment of technological evolution, marrying the age-old principles of a lathe machine with advanced computer programming to achieve unprecedented accuracy and efficiency in machining. The CNC lathe machine tool has revolutionized how materials are manipulated, making it an indispensable tool in various industries and many machine shops. Its ability to perform intricate cutting and shaping with incredible precision makes it a cornerstone in modern manufacturing processes. Whether it's metal, plastic, or wood, the CNC lathe's versatility in handling diverse materials is unmatched.

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Figure 1: Basic structure of CNC machine

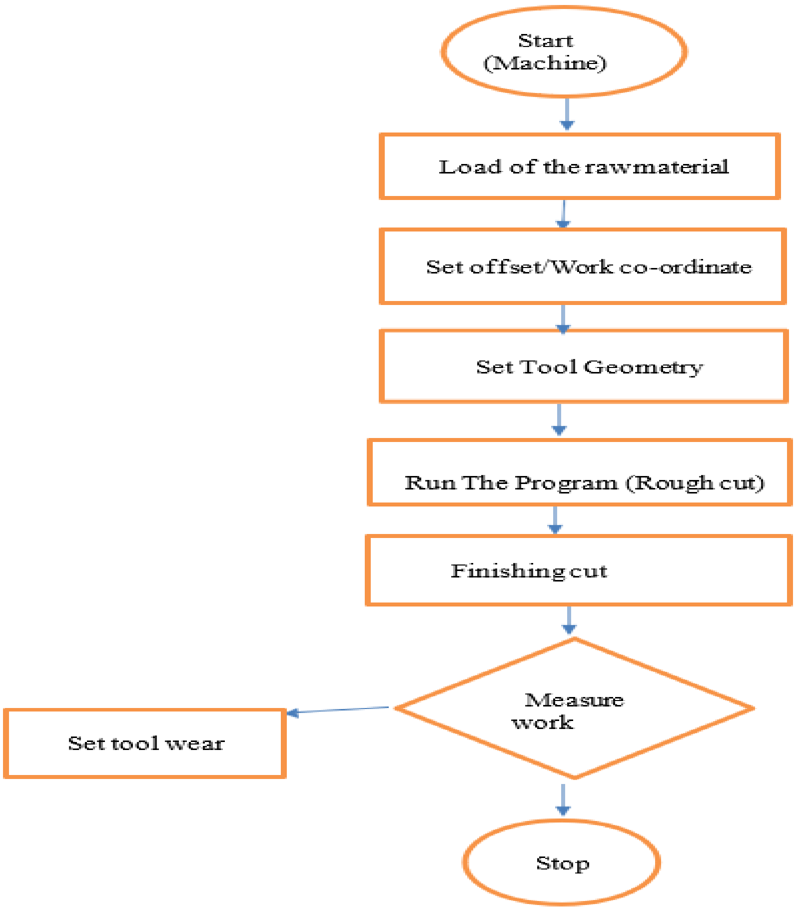

Figure 2: process of steps in flow chat

1.1 Methodology

The main aim of the investigational work is to evaluate optimum cutting condition based on Surface Roughness & MRR. Functional relationship of various variables (speed, feed, depth of cut, SR and MRR) will be produced that will be close to the experimental results. The first step in selecting the right brass alloy is understanding the strength requirements of your project. Brass is a weight, corrosion-resistant material, ideal for applications requiring strength-to-weight ratio. It offers excellent Musical instruments, horns and bells, Plumbing, hose couplings, valves, and electrical plugs and sockets etc… CNC lathe machines operate based on programmed instructions called G-code. These instructions specify the tool's movement, feed rate, depth of cut, and other parameters.

II. Literature

Kamal Hassana et. al [1]: The optimization of machining parameters in CNC turning is crucial for improving material removal rate (MRR) and process efficiency. Several studies have applied the Taguchi method to optimize cutting speed, feed rate, and depth of cut. Taguchi's orthogonal arrays help in reducing experimental efforts while maintaining accuracy in results. Researchers like Patel et al. (2018) and Singh et al. (2020) emphasized that feed rate significantly influences MRR, followed by cutting speed. ANOVA analysis has been widely used to determine the significance of process parameters. Studies on brass alloys, particularly C34000, highlight the importance of selecting appropriate cutting conditions to minimize tool wear and enhance productivity. Additionally, hybrid optimization methods integrating Taguchi with Grey Relational Analysis (GRA) and Response Surface Methodology (RSM) have been explored for multi-objective optimization. The present study builds on these findings by experimentally validating optimal machining parameters for maximizing MRR in CNC turning of C34000 brass.

Nilesh Gaddapawar et. al [2]: The optimization of machining parameters using the Taguchi method has been widely applied to improve surface roughness in polymer and metal machining. Researchers have demonstrated that the Taguchi method provides a systematic approach to parameter optimization with minimal experimental trials compared to full factorial analysis. Studies on polymer machining, including Acetal homopolymer, highlight the significance of cutting speed, feed rate, and depth of cut in determining surface roughness. Previous research indicates that feed rate has the most substantial effect on surface roughness, followed by cutting speed and depth of cut. The application of ANOVA in machining studies helps determine the statistical significance of process parameters, improving manufacturing efficiency. Additionally, MINITAB software has been extensively used for signal-to-noise (S/N) ratio analysis and response tables, making Taguchi's robust design methodology a preferred approach in industrial applications. The findings contribute to cost-effective machining with improved dimensional accuracy and surface finish.

K. Partheeban et. al [3]: Several studies have explored the optimization of machining parameters in turning operations using the Taguchi method. Taguchi's robust design approach helps minimize variations and improve machining performance by analyzing signal-to-noise (S/N) ratios and Analysis of Variance (ANOVA). Researchers have identified that parameters such as cutting speed, feed rate, and depth of cut significantly influence surface roughness and material removal rate (MRR). Previous works suggest that feed rate and depth of cut have a greater impact on surface roughness than cutting speed, while MRR is highly dependent on depth of cut. Studies utilizing orthogonal arrays (L9, L16) have demonstrated that the Taguchi method effectively identifies optimal cutting conditions with minimal experimental trials. Moreover, regression models and interaction plots derived from ANOVA provide insights into parameter relationships, aiding in performance enhancement. This review highlights the effectiveness of the Taguchi method in machining optimization for quality and productivity improvement.

S.M. Jadhav et. al [4]: The optimization of lathe machining parameters has been widely studied to improve surface roughness and material removal rate (MRR) using statistical and experimental approaches. The Taguchi method is a robust technique for reducing variability and identifying optimal machining conditions. Researchers have extensively used orthogonal arrays (L9, L16, etc.) and Analysis of Variance (ANOVA) to determine the significance of cutting speed, feed rate, and depth of cut. Studies have shown that depth of cut is the most dominant factor influencing MRR, while surface roughness is highly dependent on feed rate. Regression models, linear and nonlinear mathematical models, and interaction plots help in predicting machining responses. Additionally, confirmation experiments validate the optimized parameters for better accuracy and performance. The integration of these methodologies enables efficient process optimization, improved machining quality, and

enhanced productivity, making the Taguchi method a valuable tool for industrial applications in precision machining.
T. K Durga Bhavani et. al [5]: Optimization of machining parameters for improved material removal rate (MRR) and surface roughness has been extensively studied in turning operations. Researchers have used techniques like Taguchi's Design of Experiments (DOE) and Response Surface Methodology (RSM) to analyze the impact of spindle speed, feed rate, and depth of cut on machining performance. Studies have shown that feed rate significantly affects MRR, while surface roughness is mainly influenced by cutting speed and depth of cut. Aluminum, copper, and gunmetal exhibit different machinability characteristics, with aluminum demonstrating the highest MRR due to its lower hardness. Previous works indicate that tungsten carbide tools 21 enhance cutting efficiency by providing better wear resistance. ANOVA has been widely applied to determine the statistical significance of process parameters. Findings generally confirm that increasing cutting parameters improves MRR but deteriorates surface finish. The integration of RSM with experimental validation ensures accurate predictive modeling for machining optimization.
Pankaj Sharma, Kamaljeet Bhambri et. al [6]: Optimization of machining parameters in CNC turning has been extensively studied to improve surface roughness and material removal rate (MRR). Taguchi's method and Grey Relational Analysis (GRA) have been widely applied for multi- response optimization. Researchers have found that cutting speed, feed rate, and depth of cut significantly influence machining performance, with feed rate being a dominant factor for MRR and cutting speed affecting surface roughness. Studies on AISI H13 tool steel reveal its importance in high-speed turning applications due to its hardness and wear resistance. Taguchi's design of experiments (DOE) combined with ANOVA helps in identifying significant parameters, while GRA simplifies multi-response optimization by converting multiple objectives into a single relational grade. Several studies confirm that increasing cutting speed improves surface quality, whereas higher feed rates enhance MRR but degrade surface finish. The integration of statistical tools ensures reliable predictive models for machining parameter optimization.
Ashish Srivastava et. al [7]: Optimization of cutting parameters to enhance surface roughness in CNC turning has been extensively studied using statistical techniques like Response Surface Methodology (RSM). Researchers have identified spindle speed, feed rate, and depth of cut as the primary parameters influencing surface roughness. Studies indicate that increasing spindle speed generally reduces surface roughness, while higher feed rates and depth of cut tend to degrade surface finish. RSM has been widely used for predictive modeling and optimization, providing mathematical equations to describe the relationship between machining parameters and surface quality. ANOVA is frequently applied to determine the statistical significance of these parameters, confirming that spindle speed has the most dominant effect. Prior studies have validated RSM-based models through experimental results, showing minimal deviations between actual and predicted values. The findings consistently demonstrate that optimized machining conditions significantly improve surface finish, making RSM a reliable tool for process optimization in CNC turning.
Pathan Mohsinkhan et. al [8]: Optimization of machining parameters for CNC lathe machines has been extensively studied to enhance surface quality and material removal rate (MRR). 22 Taguchi's method robust statistical approach, is widely used for process optimization, minimizing variability while improving performance. Grey Relational Analysis (GRA) is often combined with Taguchi's method to tackle multi-objective optimization problems effectively. Studies have shown that cutting speed, feed rate, and depth of cut significantly influence surface roughness and MRR. Research indicates that surface roughness is predominantly affected by feed rate, followed by cutting speed and depth of cut, while MRR is largely dependent on depth of cut. Various works have validated these findings using ANOVA, regression analysis, and response surface methodology. The integration of machine learning techniques like artificial neural networks and genetic algorithms is also gaining traction for predictive modeling and optimization. These studies collectively contribute to improving machining efficiency and product quality in manufacturing industries.

N. Satheesh Kumar et. al [9]: Surface roughness in CNC turning is significantly influenced by spindle speed and feed rate, as demonstrated in various studies on machining carbon alloy steels. Research indicates that higher spindle speeds result in better surface finishes due to reduced cutting forces, while increased feed rates lead to higher surface roughness due to greater tool- workpiece interaction. Experimental investigations on materials like SAE8620, EN8, EN19, EN24, and EN47 confirm these trends. Several studies have used ANOVA and Taguchi methods to optimize parameters, revealing that feed rate is the most dominant factor affecting surface roughness, followed by spindle speed. Factors such as tool wear, vibrations, temperature variations, and material inconsistencies also contribute to deviations in roughness measurements. Advanced modeling techniques like response surface methodology (RSM) and machine learning (ANN, GA) are being employed to predict and optimize surface roughness efficiently. These findings are essential for improving machining precision in industrial applications.
Gaurav Pant et. al [10]: Material removal rate (MRR) is a crucial performance metric in machining, directly affecting productivity and cost efficiency. Several studies have investigated the impact of machining parameters—such as cutting speed, feed rate, and depth of cut—on MRR and surface roughness. Taguchi's method has been widely used for process optimization due to its systematic approach in experimental design, often combined with ANOVA for statistical significance analysis. Research indicates that cutting speed and depth of cut significantly influence MRR, while feed rate has a dominant effect on surface roughness. Advanced optimization techniques like Fuzzy Logic, Genetic Algorithms, and 23 Grey Relational Analysis have also been explored for improving machining efficiency. Additionally, studies suggest that incorporating cutting fluids and analyzing tool wear can further enhance machining performance. Future research directions include extending similar analyses to other machining processes such as milling and grinding, as well as studying diverse materials for broader applicability.
Shailendra Pawanr et. al [11]: The optimization of machining parameters is essential for improving manufacturing efficiency, reducing energy consumption, and enhancing product quality. Researchers have employed various methods such as the Taguchi method, Response Surface Methodology (RSM), and Artificial Intelligence (AI)-based approaches to optimize machining conditions. Among these, Grey Relational Analysis (GRA) has been widely used for multi- objective optimization, providing a means to balance conflicting responses like surface roughness and power consumption. However, GRA may not always offer the most precise ranking of alternatives. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) has emerged as an effective decision making tool for multi-criteria optimization, allowing the simultaneous evaluation of multiple performance indicators. Several studies have demonstrated the benefits of integrating TOPSIS with experimental design methods like Taguchi. However, due to variations in optimization results, validation through confirmation experiments is necessary to determine the most effective approach for machining parameter optimization.
M. Aramesh et. al [12]: Titanium Metal Matrix Composites (Ti-MMCs) are widely used in aerospace, biomedical, and other high performance applications due to their excellent strength to-weight ratio, high stiffness, and wear resistance. However, their poor machinability, caused by the presence of hard ceramic reinforcements, leads to excessive tool wear and poor surface finish. Researchers have explored various optimization techniques to enhance machinability, including Response Surface Methodology (RSM), Artificial Neural Networks (ANNs), and meta-modeling approaches. Kriging meta-modeling has emerged as a powerful tool for predicting machining responses by constructing surrogate models based on experimental data. Evolutionary multi objective optimization techniques, such as the Strength Pareto Evolutionary Algorithm (SPEA), have been employed to determine optimal cutting parameters that balance tool wear, surface roughness, and productivity. While existing studies provide insights into machining Ti-MMCs, further research is needed to refine optimization strategies for different machining conditions and industrial constraints.

Amit Sahu et. al [13]: Infrared (IR) image enhancement is a crucial technique for improving 24 the visibility of IR images, particularly in low-light and high-noise environments. Traditional spatial and spatiotemporal homomorphic filtering (SHF and STHF) methods enhance IR images by reducing noise and improving contrast. SHF processes images spatially, while STHF integrates temporal data for faster convergence. However, SHF generally produces better quality results. Wavelet transform-based enhancement has gained attention due to its ability to decompose images into multiple frequency subbands, allowing localized contrast adjustments. Homomorphic filtering, which separates illumination and reflectance components, is often combined with wavelet transforms to enhance image details. Studies have shown that applying homomorphic processing to wavelet subbands and then reconstructing the image leads to superior enhancement. The proposed approach integrates homomorphic filtering with wavelet transform to improve IR image clarity and preserve crucial details. This method is expected to generate high-information- content images, making it useful for applications in surveillance, medical imaging, and remote sensing.

G.V.N.D.Satya Surya Kiran et. al [14]: Optimizing cutting parameters in machining Inconel 718, a nickel-based superalloy, is essential due to its high strength, work hardening, and poor thermal conductivity. Traditional machining methods often lead to excessive tool wear and high cutting forces. Taguchi optimization and Response Surface Methodology (RSM) are widely used to optimize machining parameters and improve tool performance. Previous studies highlight that cutting speed, feed rate, and depth of cut significantly influence cutting forces, tool wear, and surface finish. Among these, depth of cut is the most dominant factor affecting cutting forces. Taguchi and RSM approaches help in determining optimal cutting conditions for minimizing stresses and improving machining efficiency. Recent research confirms that using carbide tools with optimized parameters—such as a higher cutting speed (60 m/min), lower feed (0.05 mm/rev), and minimal depth of cut (0.2 mm)—reduces stress and enhances tool life. These findings contribute to efficient machining of Inconel 718 with improved accuracy and performance.

Kantheti Venkata Murali Krishnam Raju et. al [15]: This research focuses on modeling and optimizing cutting parameters to minimize surface roughness in end milling of 6061 aluminum alloy using HSS and carbide tools under dry and wet conditions. Multiple regression analysis with analysis of variance is applied to assess the impact of cutting parameters on surface roughness. Second- order mathematical models are developed based on experimental data. Genetic algorithms (GA) are employed for optimization, identifying the best cutting parameter combinations for improved surface quality. The GA-predicted values are validated against 25 experimental results, showing consistency and reliability. Key findings include that feed rate significantly influences surface roughness, with roughness increasing as feed rate rises and decreasing with increased spindle speed. Carbide tools yield smoother surfaces compared to HSS tools, and coolant use further reduces roughness. The approach is applicable to other machining processes, and the study can be expanded to explore more parameters, tool types, and materials for broader applicability.

J. Yadu Krishnan et. al [16]: This study investigates the influence of cutting parameters on surface roughness (SR), cutting temperature (CT), and cutting force (CF) during the turning of C352 brass alloy using a conventional lathe and high-speed steel (HSS) tools. The selected cutting parameters are cutting speed (s), feed rate (f), and depth of cut (d), and the experimental design follows a 3-factor, 3-level Taguchi L9 orthogonal array. ANOVA is conducted to determine the significant factors. Key findings include that higher cutting speeds result in lower cutting forces and improved surface finish, while increased depth of cut negatively affects surface quality. The rankings of cutting parameters based on their impact are: cutting speed (1st), depth of cut (2nd), and feed rate (3rd) for CF, SR, and CT. The optimal conditions for minimizing CF, SR, and CT are a cutting speed of 900 rpm, depth of cut 0.15 mm, and feed rate 0.3 mm/rev, yielding CF of 9.4 kgf, SR of 1.9 mm, and CT of 59°C.

G. Moses Dayan et. al [17]: This study focuses on optimizing machining parameters during CNC turning of Ti-6Al-4V titanium alloys using carbide tools. The aim is to reduce surface roughness, temperature, and improve tool life while maximizing metal removal rate. Taguchi's L9 array was employed to design the experiments, considering varying cutting speeds, feed rates, and depths of cut. The results show that feed rate has the most significant impact on surface roughness, depth of cut affects tool life, and spindle speed is the key factor influencing temperature. The study concludes that surface roughness is primarily influenced by feed rate, while spindle speed and depth of cut have lesser effects. Temperature is impacted by spindle speed, followed by feed rate and depth of cut. Metal removal rate is mostly affected by depth of cut, followed by speed and feed rate. The models developed using Taguchi's method provided good agreement with experimental results, and the regression equations show a linear relationship among parameters.

Sujit Kumar Jha et. al [18]: This study applies the Taguchi method to optimize the process parameters— cutting speed, feed rate, and depth of cut—during the turning of mild steel with TiN-coated carbide tools. The analysis of variance (ANOVA) is used to identify the significant 26 factors affecting the material removal rate (MRR). An orthogonal array is designed, and the signal-to- noise (S/N) ratio is calculated to analyze the performance characteristics in dry turning operations. The results show that feed rate is the most significant factor influencing MRR, followed by depth of cut and cutting speed. Confirmation experiments validate the optimal parameters, leading to a 347.2% improvement in MRR from initial conditions. ANOVA and S/N ratio analysis provide a systematic approach for optimizing cutting parameters, with the optimal settings identified as cutting speed of 60 m/min, feed rate of 0.22 mm/rev, and depth of cut of 1.5 mm. The findings highlight the importance of feed rate in maximizing MRR.

M. Aramesh et. al [18]: This study focuses on optimizing cutting conditions to minimize tool wear and surface roughness during the machining of titanium metal matrix composites (Ti-MMCs). Ti MMCs are valued for their high mechanical properties, wear resistance, and low weight, but their abrasive ceramic reinforcements pose challenges in machinability. The study investigates three independent parameters: cutting speed, feed rate, and depth of cut, with surface roughness and tool wear rate as response parameters. Kriging meta-modeling is used to fit a model for these parameters, and the optimization is performed using the Strength Pareto Evolutionary Algorithm (SPEA), a multi-objective optimization technique. The results categorize the optimization outcomes into three zones, each suited for different manufacturing priorities. Zone 1 focuses on maximizing productivity with tolerable surface roughness, ideal for roughing operations, while Zone 3 prioritizes surface quality. Zone 2 offers a balance between surface quality and productivity, making it suitable for general machining tasks.

Kamaljeet Bhambri et. al [19]: Optimization of machining parameters in CNC turning has been extensively studied to improve surface roughness and material removal rate (MRR). Taguchi's method and Grey Relational Analysis (GRA) have been widely applied for multi response optimization. Researchers have found that cutting speed, feed rate, and depth of cut significantly influence machining performance, with feed rate being a dominant factor for MRR and cutting speed affecting surface roughness. Studies on AISI H13 tool steel reveal its importance in high- speed turning applications due to its hardness and wear resistance. Taguchi's design of experiments (DOE) combined with ANOVA helps in identifying significant parameters, while GRA simplifies multi-response optimization by converting multiple objectives into a single relational grade. Several studies confirm that increasing cutting speed improves surface quality, whereas higher feed rates enhance MRR but degrade surface finish. The integration of statistical tools ensures reliable predictive models for machining parameter optimization.

Eduardo Ribeiro et. al [20]: This study focuses on optimizing the milling process to achieve 27 high-quality surfaces in hardened steel (steel 1.2738), which is crucial for subsequent coatings that provide protection against corrosion, wear, and improve decorative finishes. The effects of four machining parameters—cutting speed, feed rate, radial depth, and axial depth—on surface roughness were analyzed using the Taguchi optimization method. A L16 orthogonal array was used, with two levels for each parameter, leading to 16 experimental tests. The surface roughness measurements from these tests were analyzed using analysis of variance (ANOVA). The results indicate that radial cutting depth and the interaction between radial and axial depths have the most significant impact on surface roughness, with contributions of about 30% and 24%, respectively. The study demonstrates the effectiveness of the Taguchi method in identifying key parameters and their interactions for minimizing surface roughness, offering valuable insights for improving surface quality in milling operations.

III. Conclusion

In this study the analysis of confirmation experiment and the design of control parameter with their levels & parameters to find the optimal control parameter to minimize the surface roughness and maximize Metal removal rate. 1) In this project work, the Diameters tool are utilized to get the surface qualities, Out of there brass work piece 25mm diameter tool is selected based on experimental data, in which it provides better surface quality . 2) Parametric study shows the effect of different parameters i.e Speed, feed, depth of cut etc. on the surface roughness.

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