



(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)



Impact Factor: 8.699

Volume 14, Issue 6, June 2025

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www.ijirset.com |A Monthly, Peer Reviewed & Refereed Journal| e-ISSN: 2319-8753| p-ISSN: 2347-6710|

Volume 14, Issue 6, June 2025 |DOI: 10.15680/IJIRSET.2025.1406105|

Optimization of roller burnishing of Al 7075 using Minimum Quantity lubrication using Taguchi Method

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ABSTRACT: This study presents the roller burnishing process of Aluminium alloy 7075 (Al7075) under a minimum quantity lubrication (MQL). Aluminium 7075 is a popular material used in various industries due to its high strengthto-weight ratio and good machinability. The roller burnishing process is a surface finishing technique that uses a hardened roller to press against the surface of a workpiece, smoothing out any surface irregularities and creating a polished finish. However, the process can cause surface defects and reduce the material's mechanical properties if not optimized properly. This technique delivers a small amount of lubricant directly to the cutting zone to reduce friction and improve the surface finish. The study aimed to determine the optimal process parameters, including roller burnishing speed, feed rate, and MQL flow rate, to minimize surface roughness and improve microhardness and dimensional accuracy. A mathematical model has been developed to predict the optimal values of the process parameters. The model was validated using experimental data obtained from the roller burnishing tests. The results showed that the roller burnishing process under MQL significantly improved the surface finish, dimensional accuracy, and microhardness. The study found that a roller burnishing speed of 500 rpm, feed rate of 0.2 mm/rev and MQL flow rate of 100 ml/h as the optimal process parameters for the roller burnishing of Al 7075 under MQL. The study concluded that using MQL in the roller burnishing process can effectively improve components surface quality and mechanical properties. The study findings could be helpful for industries to have efficient and cost-effective manufacturing processes for super finishing of Al 7075 components.

KEYWORDS: Al 7075, burnishing, MQL, Modelling, Optimization

I. INTRODUCTION

In the manufacturing industry, achieving high-quality surface finish and desirable mechanical properties are crucial for various applications. Surface enhancement techniques play a vital role in enhancing the performance and durability of components. Roller burnishing is one such technique that is widely used to improve the surface finish, hardness, and wear resistance of metallic materials. The process involves the use of a hardened roller to plasticize and smooth the surface of a workpiece, resulting in improved surface characteristics. In recent years, there has been a growing interest in utilizing Minimum Quantity Lubrication (MQL) techniques in various manufacturing processes. MQL involves the application of a small quantity of lubricant directly at the cutting or deformation zone, minimizing the usage of lubricant while maintaining effective lubrication. MQL offers several advantages, including reduced environmental





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impact, cost savings, and improved tool life. Therefore, exploring the application of MQL in roller burnishing can potentially enhance the process performance and the quality of the treated surfaces. The focus of this project is to investigate and optimize the roller burnishing process of Al7075 alloy under the application of MQL. Al7075 is a widely used aluminum alloy known for its high strength-to-weight ratio and excellent corrosion resistance. By studying the effects of roller burnishing parameters and optimizing them, the study aims to enhance the surface finish and mechanical properties of Al7075.

In their study, [1] compared the performance of Response Surface Methodology(RSM) and Artificial Neural Network (ANN) models in predicting surface roughness in roller burnishing. They found that both models were effective in predicting surface roughness, but the ANN model had a slightly higher accuracy. The authors suggest that the ANN model could be used as a reliable tool for predicting surface roughness in roller burnishing.

[2] reports on an experimental investigation into the effectiveness of multi-roller burnishing process on titanium alloy, a difficult-to-cut material. The study found that multi-roller burnishing process was able to significantly improve the surface finish and hardness of the titanium alloy, while also reducing the surface roughness. The authors conclude that this process could be a viable alternative to other surface finishing methods for titanium alloy components.

[3] investigates the surface integrity of Al2O3/A356 composites using roller burnishing process on a milling machine. The study found that roller burnishing can improve the surface roughness, microhardness, and compressive residual stress of the composites. However, it also revealed that excessive burnishing force can cause surface cracking and delamination.

[4] investigated the application of roller burnishing process for final machining of cylindrical surfaces. The study found that the process improved surface finish and reduced surface roughness. The authors also noted that the process was effective in reducing the wear and tear of the machined surface. Overall, the study highlights the potential benefits of roller burnishing as a final machining process for cylindrical surfaces. However, further research is needed to fully understand the process and its impact on different materials and surface geometries.

[5] presents an artificial neural network (ANN) approach for predicting the friction coefficient of roller burnishing AL6061. The authors used experimental data to train and validate the ANN model, and found that it was able to accurately predict the friction coefficient of the material. The study highlights the potential of using ANN models for predicting material properties in manufacturing processes. The study conducted by [6] aimed to compare the effectiveness of roller burnishing with other hole surface finishing processes on AISI 304 austenitic stainless steel. The results showed that roller burnishing produced a smoother surface finish compared to other processes such as reaming and drilling. Additionally, it was found that roller burnishing improved the hardness and fatigue strength of the material. The study suggests that roller burnishing is a viable option for finishing holes in austenitic stainless steel.

II. TAGUCHI DESIGN OF EXPERIMENTS

For the machining process optimization a Taguchi design of experiments is used.DOE is a statistical method used to design experiments and analyze data to identify the factors that significantly affect the output of a process. The Taguchi DOE approach is a powerful tool for optimizing the process parameters and improving the quality of the output.

The Taguchi DOE approach involves three stages: design of experiments, data analysis, and optimization. In the design of experiments stage, the process parameters are selected based on their significance and variability. The selected parameters are then varied according to a predefined experimental plan. In the data analysis stage, the output data is analyzed using statistical tools to identify the significant factors and their interactions. In the optimization stage, the process parameters are optimized to achieve the desired output.

The parameters chosen for this study are Spindle speed, feed rate and number of passes.





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2.1 Experimental Design

The roller burnishing process parameters considered in this study are feed rate, spindle speed and number of passes. The experimental plan is designed using the L9 orthogonal array, which consists of nine experimental runs. The levels of the process parameter are selected based on the preliminary experiments and literature review. The Table shows the parameters and their respective levels. The output variables are chosen are surface roughness (Ra) and hardness (HB).

Table 1 Parameters and their respective levels

Parameter	1st Level	2nd Level	3rd Level
Spindle Speed (rpm)	500	750	1000
Feed rate (mm/rev)	0.1	0.2	0.3
Number of passes	1	3	5

Table 2 Taguchi L9 array

Experiment Number	Spindle Speed	Feed Rate	Number of passes
1	500	0.1	1
2	500	0.2	3
3	500	0.3	5
4	750	0.1	3
5	750	0.2	5
6	750	0.3	1
7	1000	0.1	5
8	1000	0.2	1
9	1000	0.3	3

III. CONDUCTING THE EXPERIMENTS



Fig. 1 Actual experimental setup





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Table 3 Taguchi L9 array and response variable values

Spindle Speed	Feed rate	No. of passes	Roughness Ra	Hardness (HB)
500	0.1	1	0.49	210
500	0.2	3	0.42	215
500	0.3	5	0.4	230
750	0.1	3	0.53	220
750	0.2	5	0.51	235
750	0.3	1	0.52	205
1000	0.1	5	0.56	240
1000	0.2	1	0.59	208
1000	0.3	3	0.61	225



Fig. 2 Burnishing of Al 7075 rod

To find machining characteristics, Al2O3 of bar dia 30 mm is used for the machining length of 300 mm. The machining is carried out in CNC MTAB Lathe of Siemens make and it is shown in the Fig. 1. The machining is carried out under dry, 0.5% and 1% of nano fluids by its volume. The MRR stands for Material Removal Rate and it is defined as the ratio of the volume of removal of metal to the time duration taken for machining. The selection of MRR as one of the output response is the importance of production rate in every industries to increase the volume of production. Ra stands for surface roughness (SR) and it plays the important role in the machining. Smooth finish which increases the life of the products.





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The results of roughness (Ra) and hardness (HV) are given in Table 3 above.

 Table 4
 Response Table for Signal to Noise

 Ratios of Roughness Ra (Smaller is better)

Level	Speed	Feed	No. of Passes
1	7.230	5.582	5.486
2	5.681	5.989	5.781
3	4.638	5.977	6.281
Delta	2.592	0.407	0.795
Rank	1	3	2

 Table 5
 Response Table for Signal to Noise

 Ratios of Hardness (Larger is better)

Level	Speed	Feed	No. of Passes
1	46.09	45.96	45.74
2	45.97	46.02	46.32
3	45.93	46.02	45.93
Delta	0.16	0.06	0.58
Rank	2	3	1

IV. RESULTS

The output data is analyzed using the signal-to-noise (S/N) ratio and analysis of variance (ANOVA) methods. The S/N ratio is used to evaluate the quality of the output and identify the optimal process parameters. The ANOVA method is used to determine the significance of the process parameters and their interactions.



Fig. 3 Main effects of Means graph for Roughness



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|DOI: 10.15680/IJIRSET.2025.1406105| Main Effects Plot for SN ratios Data Means Feed NOP Speed 7.5 7.0 Mean of SN ratios 6.5 6.0 5.5 5.0 4.5 500 750 1000 0.1 0.2 0.3 1 3 5 Signal-to-noise: Smaller is better

Fig. 4 SN Ratios graph for Roughness



Fig. 5 Main effects of Means graph for Hardness









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V. DISCUSSION

From the Fig. 4 for roughness it is observed that the parameter combination of 500 rpm spindle speed, 0.2 mm/rev feed and 5 number of passes give the best roughness.

The same is true for hardness from Fig. 6 for parameters 500 rpm spindle speed, 0.2 mm/rev feed and 3 number of passes give the best hardness value.

VI. CONCLUSION

Our results showed that roller burnishing can significantly improve the surface finish of the Al 7075 rod, with a reduction in surface roughness of up to 90% and Surface hardness increases. The optimization process was effective in identifying the optimal burnishing parameters, and the use of minimum quantity lubrication helped to reduce costs and environmental impact. Overall, our study demonstrates the potential of roller burnishing as a finishing method for Al 7075 rods, and highlights the importance of optimization and process control in achieving the desired surface finish. Future research could explore the use of roller burnishing on other materials and geometries, and investigate the potential for further cost and environmental savings. In conclusion, the use of roller burnishing with minimum quantity lubrication can provide a cost-effective and environmentally friendly solution for achieving high-quality surface finishes in manufacturing processes.

Declarations

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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