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Innovative Enhancements in Surface Quality and Hardness of Aluminium Alloy 2024 through an Optimized Burnishing Process

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Abstract: The burnishing process showcases a novel approach for significantly improving the surface quality and hardness of metals, particularly aluminium, copper, and brass. This paper presents a novel approach to optimize the burnishing process of Aluminium 2024 by simultaneously analyzing the effects of spindle speed, feed rate, and burnishing force, a comprehensive method that has not been addressed in prior studies. Utilizing a specially designed roller-based tool with a lathe machine, we systematically varied key parameters—spindle speed, feed rate, and burnishing force—through a full factorial design with two repetitions. Advanced statistical analysis was conducted using Minitab software to assess the effects of these parameters on surface roughness and hardness, employing regression methods for precise predictions. Remarkably, the results demonstrated that optimal surface roughness (Ra = 0.05 μm) was attained at a feed rate of 0.11 mm/rev, spindle speed of 1000 r/min, and burnishing force of 1000 N. This research not only highlights the effectiveness of the burnishing process in enhancing the mechanical properties of aluminium alloys but also introduces innovative methodologies that pave the way for improved industrial applications. Future studies will investigate the effects of burnishing in corrosive environments and its impact on material strength.

Keywords: Aluminium Alloy 2024, Burnishing Process, Mechanical Properties, Statistical Analysis, Surface Quality

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Research paper

1 INTRODUCTION

The demand for advanced materials with enhanced mechanical properties and superior surface characteristics continues to grow in various industries, particularly in aerospace, automotive, and manufacturing sectors. Aluminium Alloy 2024, known for its high strength-to-weight ratio and excellent fatigue resistance, has become a preferred choice in applications where performance and durability are paramount [1]. Components made from this alloy are frequently subjected to rigorous conditions, making their surface quality and hardness critical factors in ensuring longevity and reliability.

Importance of Surface Quality and Hardness

Surface quality plays a crucial role in determining the overall performance of engineering components. It influences not only the aesthetic appeal of the finished product but also its mechanical properties, including wear resistance, fatigue strength, and corrosion resistance. A smooth surface finish can significantly reduce friction and wear, leading to prolonged service life and improved efficiency [2]. Conversely, poor surface quality can result in premature failure of components, increased maintenance costs, and reduced operational efficiency. In this study, several key parameters are crucial for understanding the burnishing process of Aluminium 2024. Spindle speed refers to the rotational speed of the tool or workpiece, typically measured in revolutions per minute (rpm). The feed rate is defined as the distance that the tool advances during one complete revolution, expressed in millimeters per revolution (mm/rev). Lastly, burnishing force is the force exerted by the burnishing tool against the workpiece, measured in newtons (N). Understanding these terms is essential for comprehending the methodology and results presented in this paper. Hardness, on the other hand, is a measure of a material's resistance to deformation and wear. Increased hardness often correlates with enhanced wear resistance, making it a desirable characteristic for components subjected to high loads and abrasive environments [3]. Consequently, optimizing both surface quality and hardness is essential for achieving high-performance standards in applications involving Aluminium Alloy 2024.

Traditional Surface Finishing Techniques

Traditional surface finishing methods, such as grinding, honing, and polishing, have been widely used to improve surface quality. Each of these techniques has its advantages and limitations. For instance, grinding is effective for removing material and achieving precise dimensions, but it can introduce surface defects and residual stresses that may compromise material performance [4]. Honing is suitable for achieving high geometric accuracy but can be time-consuming and costly [5]. Polishing, while capable of producing a mirror-like finish, often requires multiple steps and extensive labor. These traditional methods also tend to generate significant waste and can be less environmentally friendly due to the use of cutting fluids and abrasives. As industries strive for sustainability and cost-effectiveness, there is a growing need for alternative finishing techniques that can deliver superior results with reduced environmental impact [6].

The Burnishing Process

Burnishing is an innovative surface finishing technique that has gained popularity for its ability to enhance surface quality without material removal. This chipless process involves the plastic deformation of the surface layer through the application of pressure, resulting in a smoother finish and increased hardness [7]. Unlike traditional machining methods, burnishing minimizes waste and can be performed in a single operation. One of the key advantages of burnishing is its ability to introduce compressive residual stresses in the material. These stresses can significantly improve the fatigue strength and wear resistance of components, making burnishing particularly beneficial for high-performance applications [8]. Additionally, the burnishing process can often be completed in less time than traditional methods, leading to increased productivity and cost savings.

Factors Influencing the Burnishing Process

Despite its advantages, the effectiveness of the burnishing process is highly dependent on several key parameters.

These include:

1. Spindle Speed: The rotational speed of the workpiece can significantly affect the burnishing action. Higher spindle speeds may enhance surface finish but can also lead to increased heat generation, which may negatively impact the material properties [3].
2. Feed Rate: The speed at which the burnishing tool moves across the workpiece influences the depth of plastic deformation. An optimal feed rate is necessary to achieve the desired surface quality without compromising the mechanical properties [9].
3. Burnishing Force: The amount of force applied during the burnishing process directly impacts the level of plastic deformation. Adequate force must be applied to induce the necessary surface changes while avoiding excessive material removal or damage [4].
4. Tool Material and Geometry: The material and design of the burnishing tool play a critical role in the process. Harder tool materials can withstand greater forces and pressures, while specific geometries can enhance the effectiveness of the burnishing action [9].
5. Lubrication: The use of lubricants during the burnishing process can reduce friction and heat

generation, leading to improved surface quality. Proper lubrication is essential for achieving optimal results [10].

Research Gap and Objectives

While burnishing has been applied to various materials, comprehensive studies focusing specifically on Aluminium Alloy 2024 and its unique properties are limited. Previous research has demonstrated the effectiveness of burnishing in improving surface quality and hardness in different alloys; however, the systematic optimization of burnishing parameters for 2024 aluminium remains an underexplored area [7].

This study aims to fill this gap by investigating the innovative application of burnishing to Aluminium Alloy 2024. We will systematically vary key parameters—spindle speed, feed rate, and burnishing force—using a specially designed roller-based tool mounted on a lathe machine. A full factorial design approach will enable us to assess the effects of these parameters on surface roughness and hardness comprehensively.

Methodology Overview

In this study, we employ advanced statistical analysis using Minitab software to evaluate the data collected from the burnishing experiments. This analysis will provide insights into the relationships between the burnishing parameters and the resulting surface characteristics. The use of regression methods will facilitate precise predictions of surface roughness and hardness based on the selected parameters.

Preliminary findings from our experiments indicate that optimal surface roughness (Ra = 0.05 μm) can be achieved under specific conditions—namely, a feed rate of 0.11 mm/rev, a spindle speed of 1000 r/min, and a burnishing force of 1000 N. These results highlight the potential of the burnishing process to enhance the mechanical properties of Aluminium Alloy 2024 significantly.

Fig. 1 Burnishing tool installed on the dynamometer.

Future Directions

The findings of this research not only validate the effectiveness of the burnishing process but also pave the way for improved industrial applications. Future studies will explore the effects of burnishing in corrosive environments and its impact on material strength, further expanding the applicability of this technique. Additionally, the investigation of alternative lubricants and tool materials may lead to further enhancements in the burnishing process. (“Fig. 1”).

2 METHODOLOGIES

The purpose of the current research is to design and build a burnishing tool to create the most desirable surface quality and hardness on non-metals that are not capable of creating a suitable surface quality (maximum Ra 1.0) with other machining operations. In addition to creating surface quality, such tools can cause surface hardness by creating compressive residual stress.

Devices and Tools

TN50BR model lathe is used to perform various burnishing operations. The control of deviations and slacks in the lathe should be done so that it does not exceed the limit value. It is clear that if the deviations and clearances of the machine tools are more than the specified limit, it will cause the failure or poor quality of the production part, and as a result, the results of the tests will be wrong. Allowed radial clearance in the lathe is 0.003 to 0.005mm. Axial clearance is taken by angular contact bearings. These bearings restrain the axial force in two directions and also bear the radial force behind the spindle. Roughness Tester, model RT-620 is a portable device used to measure the roughness of machined surfaces. A portable hardness tester based on the LEEB method has been used to measure hardness.

A special roller-based burnishing tool is used (“Fig. 2”). The set of experiments was carried out by this designed and built tool. This tool is used for burnishing on external surfaces with a round cross-section. The burnishing tool roll (7) can be replaced and can be made with different dimensions and materials. After being placed on the work piece, this roll is rotated by two support rollers (10) and performs the burnishing operation. In addition to the dynamometer, the burnishing force can be determined by the displacement of the spring, which is measured by the indicator clock. The base of this burnishing tool is closed by four screws on the dynamometer of the lathe. The dynamometer is used to measure the forces on the tool, which is developed based on piezo technology and is installed under the burnishing tool.

Aluminium is one of the light metals with a density of 2.7. Its corrosion resistance is excellent due to the existence of a sticky and stable layer of Aluminium oxide on its surface. In other words, this oxide layer, whose thickness is about 0.025 microns, protects Aluminium against most corrosive substances. 2024 Aluminium alloy is used for making parts such as the fuselage and wings of airplanes due to its special properties such as special strength, high toughness, corrosion resistance, and good fatigue [10].

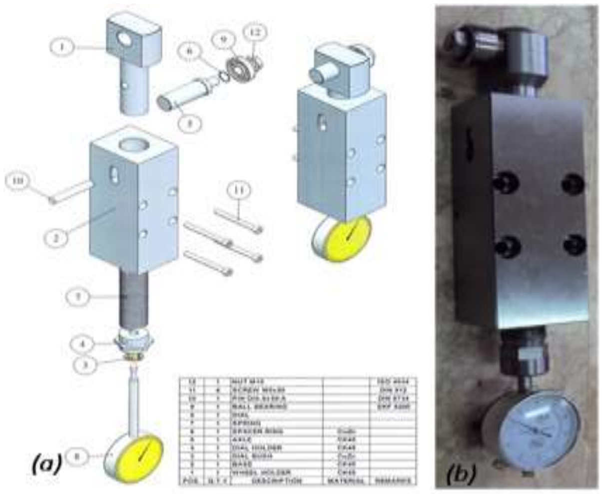

Fig. 2 Roller Burnishing Tool: (a): designed using CAD software, and (b): prototype.

The originality of Aluminium alloy 2024 including chemical composition, mechanical properties, and physical properties must be obtained from the seller or experimental tests.

Experiment Design

Many factors influence the output of this process, but the most significant parameters affecting the response variables in this research are:

Burnishing Rotation Speed: The number of rotations of the workpiece, measured in revolutions per minute (rpm).

Burnishing Advance: The feed rate of the burnishing tool for each revolution of the workpiece, measured in (mm/rev).

Burnishing Force: The force applied by the tool to the workpiece, measured in newtons. Alternatively, the depth of cut can be used as a substitute for burnishing force, measured in millimeters.

Each factor is tested at three different levels. “Table 1” presents the levels for each parameter, including spindle speed, feed rate, and burnishing force.

Table 1 The number of levels that can be obtained by each factor and its values in the burnishing test

N.	1	2	3	4	5	6	7	8	9
test	a1b1c1	a1b1c2	a1b1c3	a1b2c1	a1b2c2	a1b2c3	a1b3c1	a1b3c2	a1b3c3
N.	10	11	12	13	14	15	16	17	18
test	a2b1c1	a2b1c2	a2b1c3	a2b2c3	a2b2c2	a2b2c3	a2b3c1	a2b3c2	a2b1c1
N.	19	20	21	22	23	24	25	26	27
test	a3b1c1	a3b1c2	a3b1c3	a3b2c1	a3b2c2	a3b2c3	a3b3c1	a3b3c2	a3b3c3

“Table 2” is actually the same test plan based on the full factorial method. In this plan, three main factors each with three constant values are entered into the experiment, and in total three to the power of three and equivalent to 27 experiments will be performed. Values of 355, 710, and 1000 are considered for spindle speed, values of 0.11, 0.2, and 0.4 for feed rate, and values of 300, 600, and 1000 for burnishing force.

Table 2 Experimental design utilizing the full factorial method

Input parameters to branching machining			
Set point	a1	a2	a3
Spindle speed (n,rpm)	355	710	1000
Set point	b1	b2	b3
Feed rate (F_f, mm/rev)	0.11	0.2	0.4
Set point	c1	c2	c3
Branching force (F,N)	300	600	1000

The prepared material is cut into five equal pieces, each measuring 210 mm. A center drill is then created at both ends of the pieces, which are subsequently closed and machined on the lathe, as shown in “Fig. 3”. The cutting of the outer surface of the parts is only to the extent of whitening and 0.5 mm, and two steps are created on both sides of them to close inside the chuck.

At the end, the dynamometer is installed on the superset of the lathe, and the tool is closed by four screws. During the burnishing process, the forces and torques caused by the reaction of the tool and the workpiece are applied to the dynamometer and will cause the piezoelectric-quartz strain in the dynamometer and produce an electrical signal. This produced signal is fed and amplified by communication cables to a multi-channel amplifier, and it measures the values of different forces.

After the installation of tools and workpieces, the number of tests will be performed according to their parameters and levels, in 27 test modes and two repetitions. Then the roughness and hardness values are measured and recorded in “Table 3”.

Table 3 Surface roughness and hardness values of aluminium alloy 2024 after burnishingSurface

N.	test	Ra	hardness	N.	test	Ra	hardness	N.	test	Ra	hardness
1	a1b1c1	0.1717	174	10	a2b1c1	0.1219	172	19	a3b1c1	0.1304	169
2	a1b1c2	0.1259	184	11	a2b1c2	0.0783	180	20	a3b1c2	0.0591	176
3	a1b1c3	0.0307	192	12	a2b1c3	0.0669	190	21	a3b1c3	0.0328	186
4	a1b2c1	0.1744	174	13	a2b2c3	0.1986	170	22	a3b2c1	0.1089	167
5	a1b2c2	0.1144	182	14	a2b2c2	0.1504	180	23	a3b2c2	0.0889	177
6	a1b2c3	0.0493	191	15	a2b2c3	0.0843	187	24	a3b2c3	0.0545	184
7	a1b3c1	0.1215	172	16	a2b3c1	0.2089	166.5	25	a3b3c1	0.0763	165
8	a1b3c2	0.1130	181	17	a2b3c2	0.1770	177.5	26	a3b3c2	0.0832	176
9	a1b3c3	0.0487	191	18	a2b1c1	0.1509	183.5	27	a3b3c3	0.0856	184

Minitab software is used to determine the effect of each parameter on surface roughness and hardness. It is also possible to extract the results from the effect of factors in the form of two effects. Finally, the regression equation in the roughness and hardness of the surface will be done to find the optimal state.

Fig. 3 Analog-to-digital dynamometer converter and display screen, with the workpiece secured in the device for the burnishing process.

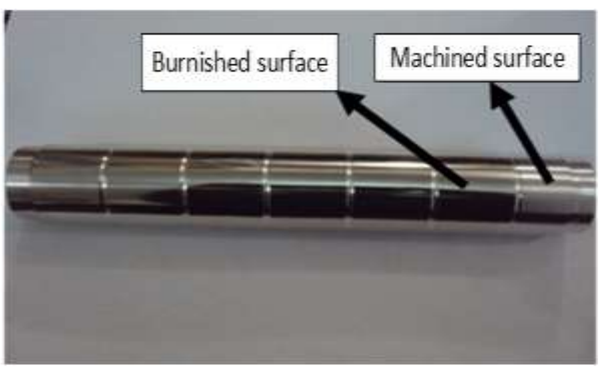

Fig. 4 Example of a burnished 2024 aluminium workpiece.

The primary workpiece has a roughness and hardness of 1.0846Ra and 164HV machined before the burnishing process. Figure 4 shows the machined workpiece surface and the burnished surface.

3 RESULTS

Burnishing of Aluminium 2024 was conducted using a lathe, and the resulting surface roughness and hardness values were obtained. This data was subsequently analyzed using Minitab software to complete the data processing. This processing includes the effect of the main factors and the effect of the two factors on the roughness and hardness of the surface. The graph related to them was extracted and the regression related to roughness and hardness was obtained according to the components including spindle speed, feed rate, and burnishing force.

The Effects of Main Factors on Surface Roughness

The separate effect of the three factors of spindle speed, feed rate and burnishing force by considering three separate values for each on the surface roughness of Aluminium 2024 was investigated (“Fig. 5”). The effect of spindle speed at speeds of 355, 710, and 1000 rpm on surface roughness was 0.137, 0.072, and 0.114 respectively. The second item is the feeding rate, which was obtained for 0.11, 0.20, and 0.40 surface roughness values of 0.100, 0.123, and 0.092, respectively. Finally, the effect of burnishing force with the values of 300, 600 and 1000N, the surface roughness was measured, and the values of 0.110, 0.096, and 0.119 were obtained, respectively. The amount of feed rate on surface roughness shows an increasing and then decreasing effect, while it shows the opposite effect for the two factors of spindle speed and burnishing force.

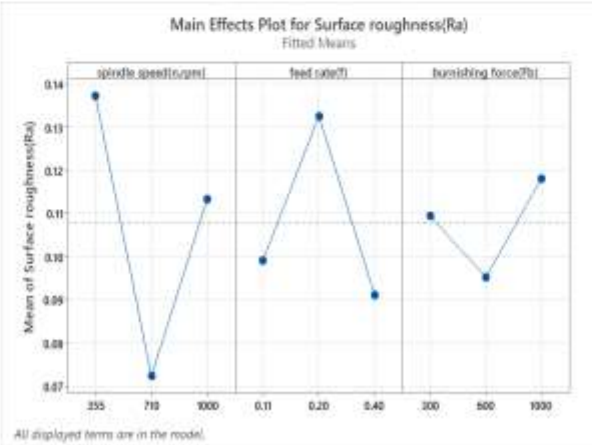

Fig. 5 Influence of Key Factors on Surface Roughness Resulting from Burnishing: (a): Spindle Speed, (b): Feed Rate, and (c): Burnishing Force.

The Effect of Two Factors on Surface Roughness

The effect of two factors on the surface roughness resulting from burnishing including spindle speed and feed rate, spindle speed and burnishing force, and feed rate and burnishing force is shown in “Fig. 6”.

Spindle Speed and Feed Rate: Increasing the spindle speed from 355 to 710 and 1000 rpm yields the following surface roughness values: at a feed rate of 0.11 mm/rev, the values are 0.137, 0.088, and 0.072 µm; at a feed rate of 0.20 mm/rev, the values are 0.168, 0.068, and 0.165 µm; and at a feed rate of 0.40 mm/rev, the values are 0.107, 0.062, and 0.103 µm, respectively.

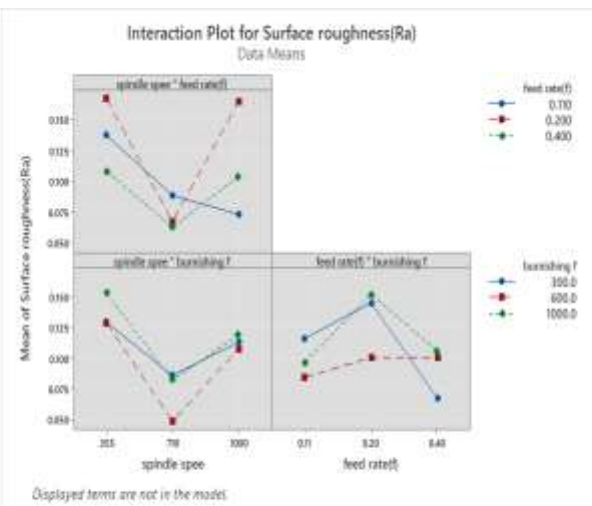

Fig. 6 Interaction effects of two parameters on surface roughness resulting from burnishing: (a): Spindle speed and feed rate, (b): Spindle speed and burnishing force, and (c): Feed rate and burnishing force.

Spindle speed and burnishing force: by increasing the spindle speed from 355 to 710 and 1000rpm, for the burnishing force 300N, the surface roughness value is 0.129, 0.088, and 0.114µm, for the burnishing force 600N, the surface roughness value is 0.130, 0.050 and 0.109µm, and for the burnishing force of 600N, the surface roughness values of 0.154, 0.084 and 0.120µm were obtained, respectively. A downward and upward trend was obtained for all three burnishing forces of 300, 600, and 1000N for surface roughness and with increasing spindle speed.

Feed Rate and Burnishing Force: As the feed rates increase to 0.11, 0.20, and 0.40 mm/rev, the following surface roughness values are observed: with a burnishing force of 300 N, the roughness values are 0.115, 0.148, and 0.069 µm; with a burnishing force of 600 N, the values are 0.087, 0.104, and 0.105 µm; and with a burnishing force of 1000 N, the roughness values are 0.100, 0.155, and 0.109 µm, respectively. In general, an upward and downward trend can be observed for the roughness surface value for three burnishing forces of 300, 600, and 1000N, and with an increase in the feed rate.

The Effects of Main Factors on Surface Hardness

The effect of three factors of spindle speed, feed rate, and burnishing force in different machining conditions was investigated separately on the surface hardness (“Fig. 7”). The results show that the spindle speed of 355, 710, and 1000 rpm causes the surface hardness to be 178.4, 181.6, and 176.9 in Vickers, respectively. With the feed rate of 0.11, 0.2, and 0.4, the surface hardness value is 174.8, 180.2, and 181.9 in Vickers respectively. By applying the burnishing force from 300 to 600 and finally 1000 N, the surface hardness was recorded as 178.3, 180.3, and 178.5, respectively. The feed rate has shown an increasing effect on the degree of hardness, while for the spindle speed and burnishing force, it reaches a maximum value from an initial value and then shows a decreasing effect.

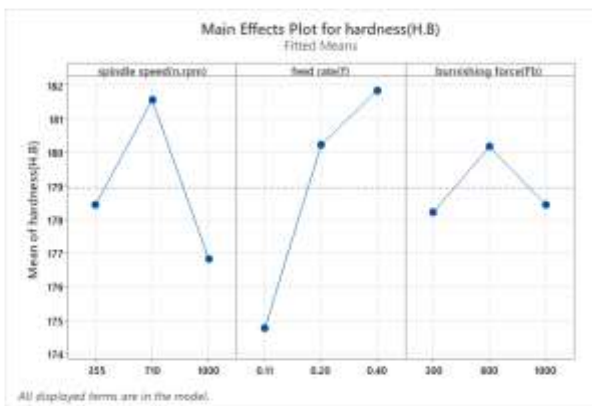

Fig. 7 Influence of key factors on surface hardness resulting from burnishing: (a): spindle speed, (b): feed rate, and (c): burnishing force

The Effect of Two Factors on Surface Roughness

The effect of two factors on the surface hardness resulting from burnishing including spindle speed and feed rate, spindle speed and burnishing force, and feed rate and burnishing force are shown in “Fig. 8”.

Spindle speed and feeding rate: by increasing the spindle speed from 355 to 710 and 1000 rpm, with a feeding rate of 0.11mm/rev values of 176, 175 and 173HV, with a feeding rate of 0.20mm/rev values of 183, 183 and 174HV, with a feed rate of 0.40 mm/rev, values of 175, 186 and 184 HV are obtained, respectively, for the surface hardness. An upward and then downward trend can be seen for the feed rate of 0.200 and 0.400 mm/rev and only a downward trend for the feed rate of 0.11 mm/rev and with increasing spindle speed for the overall surface roughness.

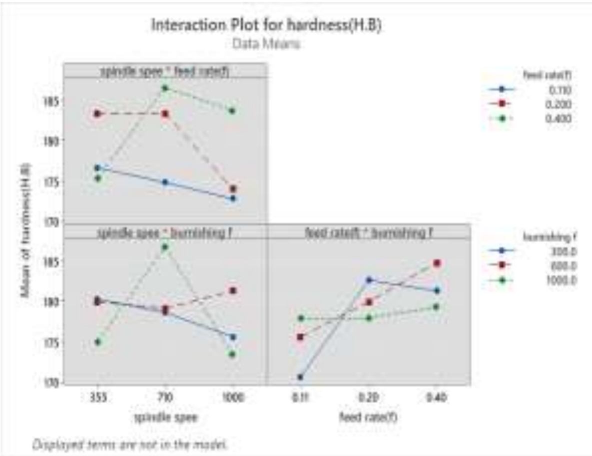

Fig. 8 Mutual effect of two parameters on hardness resulting from burnishing: (a): spindle speed and feed rate, (b): spindle speed and burnishing force, and (c): feed rate and burnishing force

Spindle speed and burnishing force: by increasing the spindle speed from 355 to 710 and 1000 rpm, for a burnishing force of 300N, surface hardness values are 180, 178, and 175HV, for a burnishing force of 600N, surface hardness values are 180, 178 and 181HV, and for the burnishing force of 600 N, surface hardness values of 174, 180 and 173HV were obtained, respectively. In total, a downward trend for the burnishing force of 300 N, a downward-upward trend for the burnishing force of 600N, and an upward-downward trend for the burnishing force of 1000N were obtained for surface hardness and with increasing spindle speed.

Feed Rate and Burnishing Force: As the feed rate increases to 0.11, 0.20, and 0.40 mm/rev, the surface hardness values are as follows: with a burnishing force of 300 N, the hardness values are 171, 183, and 181 HV; with a burnishing force of 600 N, the values are 176, 181, and 185 HV; and with a burnishing force of 1000 N, the values are 178, 178, and 179 HV, respectively. In general, an ascending-descending trend for hardness value for burnishing force 300N, an upward trend for hardness value for burnishing force 600N, and a downward trend for hardness value for burnishing force 1000N and with increasing feed rate mm/rev are visible.

Surface Roughness and Hardness Regression Equation and Model

The regression equation for surface roughness and hardness is given in equations 1 and 2, respectively. In these relationships, the effect of spindle speed, feed rate, and amount of burnishing force can be seen in the optimization.

Regression Equation for Surface roughness (Ra)= 0.10765+ 0.0294 spindle speed(n,rpm)_355 - 0.0352 spindle speed(n,rpm)_710 + 0.0058 spindle speed(n,rpm)_1000 - 0.0084 feed rate(f)_0.11 + 0.0249 feed rate(f)_0.20 - 0.0164 feed rate(f)_0.40 + 0.0019 burnishing force(Fb)_300 - 0.0124 burnishing force (Fb)_600 + 0.0105 burnishing force (Fb)_1000

(1)

Regression Equation for hardness (H.B)= 178.94 - 0.50 spindle speed(n,rpm)_355 + 2.61 spindle speed(n,rpm)_710 - 2.11 spindle speed(n,rpm)_1000 - 4.17 feed rate(f)_0.11+ 1.28 feed rate(f)_0.20 + 2.89 feed rate(f)_0.40 - 0.72 burnishing force(Fb)_300 + 1.22 burnishing force(Fb)_600 - 0.50 burnishing force (Fb)_1000 (2)

4 DISCUSSIONS

The current research focused on the burnishing process using a roller tool on Aluminium 2024, revealing critical insights into the parameters affecting surface roughness (Ra) and hardness. The findings underscore the significance of spindle speed and burnishing force while highlighting the relatively minor role of feed rate.

1. Influence of Power Parameters: The results indicate that spindle speed and burnishing force have a more pronounced effect on surface roughness than feed rate. Specifically, increasing spindle speed leads to a sharp decline in surface roughness values. For instance, at spindle speeds of 355, 710, and 1000 rpm, the surface roughness values were recorded as 0.137 µm, 0.072 µm, and 0.114 µm, respectively. This trend aligns with findings from previous studies, such as those by [7], who observed similar improvements in surface quality with increased spindle speeds in machining processes. This suggests a consensus in the literature regarding the effectiveness of higher spindle speeds in enhancing surface finish.

2. Surface Quality Improvements: The sharp decrease in surface roughness with increased spindle speed signifies the potential for achieving superior surface quality at elevated speeds. The optimal roughness achieved in this study (below 0.05 Ra) corroborates findings from [8], who reported comparable outcomes in their investigations of burnishing aluminum alloys. The improvement in surface finish can be attributed to reduced contact time between the tool and the workpiece at higher speeds, which minimizes the adhesion and defect formation on the surface.

3. Minimal Effect of Feed Rate: An intriguing aspect of the results is the minimal impact of feed rate on surface roughness across all tested ranges (0.11, 0.20, and 0.40 mm/rev). While lower feed rates yielded marginally better roughness, this does not imply their practicality in operational settings. Studies by [5] have noted similar results, emphasizing that excessive reduction in feed rate can lead to increased contact time and, consequently, a rise in surface defects due to enhanced adhesion characteristics. Thus, while a minimum feed rate may optimize surface finish, it is essential to balance it with operational efficiency.

4. Production Efficiency: The findings suggest that burnishing can be effectively performed at high speeds without compromising surface quality. The negligible effect of feed rate allows for increased production speed, as operators can focus on optimizing spindle speed to achieve desired surface characteristics. This aspect resonates with the work of [3], who highlighted the economic benefits of burnishing in terms of time savings and reduced operational costs compared to traditional machining methods.

5. Comparative Analysis with Other Methods: When contrasted with conventional machining techniques, burnishing stands out as a superior method for achieving low surface roughness values. Traditional machining often results in higher roughness, particularly at increased feed rates. Additionally, previous research by [4] demonstrated that grinding methods are prone to rapid clogging, necessitating frequent re-sharpening. This not only increases costs but also results in inefficiencies that are not observed in the burnishing process.

6. Contributions to Existing Literature: This study contributes to the existing body of knowledge by providing a detailed analysis of the relationships between spindle speed, feed rate, and burnishing force, specifically for Aluminium 2024. The regression equations derived from the analysis offer a valuable framework for predicting surface roughness and hardness based on these parameters. This aligns with the findings of [7], who also utilized statistical modeling to optimize machining parameters in similar materials.

7. Conclusion on Burnishing: Overall, burnishing emerges as a highly effective method for enhancing the surface quality of Aluminium 2024. The process not only yields superior surface finishes but also proves to be economically viable, aligning with industrial demands for efficiency and quality.

Future studies will aim to explore the effects of burnishing on the mechanical strength of Aluminium 2024 in corrosive environments, as well as the impact of chemical surface corrosion. Investigating these aspects will provide deeper insights into the durability and long-term performance of burnished surfaces, further establishing the advantages of this technique in various operational contexts. By expanding the scope of research, we aim to contribute to the development of more robust manufacturing techniques that meet the evolving needs of the industry.

5 CONCLUSIONS

The burnishing process is influenced by several critical parameters, including burnishing force, feed rate, burnishing speed, lubrication type, tool material and diameter, the number of burnishing passes, and the initial surface roughness. This study specifically focused on analyzing how these factors affect the surface roughness and micro-hardness of Aluminium 2024.

The findings indicate that burnishing force and spindle speed have a more significant impact on surface roughness compared to feed rate. Notably, the optimal surface roughness, measured at less than 0.05 Ra, was achieved at the minimum feed rate in conjunction with maximum spindle speed and burnishing force. This highlights the importance of carefully balancing these parameters to enhance surface quality.

Additionally, the design of the rollers used in the burnishing tools allows for easy replacement and adjustment, contributing to prolonged tool life and simplified maintenance. The incorporation of lubrication in the form of an oil layer further reduces friction and heat generation during the process. This oil cooler creates a smooth working layer between the roller and the workpiece, effectively preventing material from adhering to the roller and enhancing overall burnishing performance.

These results provide valuable insights into the burnishing process, demonstrating that optimized control of force parameters and spindle speed can lead to significant improvements in surface roughness. This understanding is crucial for enhancing manufacturing processes that involve Aluminium 2024, especially in applications where surface quality is essential.

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