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INFLUENCE OF FEED RATE ON SURFACE ROUGHNESS OF AL6088 ALLOY IN THE BALL BURNISHING PROCESS

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1. Introduction

Ball burnishing is a cold surface finishing process used to improve the roughness and other surface characteristics of aluminum alloys, resulting in enhanced wear, corrosion, and fatigue resistance. The process is based on the plastic deformation of surface irregularities using a hard, polished ball that is pressed against the workpiece under controlled forces.

The key ball burnishing parameters that significantly influence the final surface roughness of aluminum include the applied force, burnishing speed, number of passes, and lubrication conditions. Studies have shown that multiple passes increase surface smoothness; however, beyond a certain threshold, additional passes do not yield substantial improvements due to saturation of plastic deformation. Moreover, moderate force levels (50–300 N) combined with low burnishing speeds (~0.05 mm/rev) have demonstrated the best results in reducing the surface roughness parameter Ra.

Burnishing processes - including ball, roller, and diamond burnishing - are recognized as effective methods for enhancing the surface properties of aluminum alloys, particularly in terms of roughness reduction and hardness improvement.

Asadbeygi et al. experimentally investigated and optimized the influence of burnishing process parameters on aluminum alloy 2036, achieving a significant decrease in roughness and an increase in hardness [1]. Similarly, Cagan focused on the aluminum–lithium alloy Al8090, analyzing the effects of burnishing force, burnishing speed, and number of passes, comparing results under dry conditions and with minimum quantity lubrication (MQL), while also evaluating environmental aspects [2].

Ferencsik and Varga optimized diamond burnishing of EN AW-2011 alloy, providing detailed insights into the dependence of final roughness on selected process parameters [3]. Yuan et al. applied chaos theory to analyze the nonlinear characteristics of surface roughness in aluminum alloys, showing that burnishing parameters strongly influence surface micro-geometry [4].

Özkul [5] confirmed that ball burnishing substantially improves the surface quality of Al6013 alloy, whereas Dimitrov developed a digital model of the process - based on experiments with bronze and aluminum alloys - for parameter optimization using artificial intelligence [6]. Labuda et al. investigated burnishing of EN AW-6060 aluminum tubes, demonstrating improvements in hardness, roughness parameters, and the material ratio of welded joints [7].

A comparative study by Harish Shivalingappa [8] examined the differences between ball and roller burnishing for Al2024 alloy, while Swirad reported a reduction in surface topography amplitude of up to 94%, providing a detailed analysis of changes in areal textures [9]. Amdouni et al, using response surface methodology, modeled and optimized ball burnishing of aluminum alloy 2017A-T451, identifying optimal parameters for reducing roughness and increasing microhardness [10].

Overall, the reviewed literature confirms that optimizing burnishing process parameters - including force, speed, number of passes, and lubrication conditions - can lead to substantial improvements in the surface integrity of aluminum alloys. These findings provide a solid foundation for further research aimed at tailoring the process to specific technical requirements and sustainable manufacturing practices.

The authors in this paper [11, 12, 13, 14, 15] address the burnishing process and the influence of its parameters on the surface finish quality of various materials, including wood, aluminum alloys, and steel alloys.

In this study, experimental investigations were carried out on Al6088 alloy using a specially designed ball burnishing tool on a universal lathe. The aim was to analyze the influence of feed rate on surface roughness parameters (Ra and Rz) and to evaluate surface characteristics through Abbott–Firestone (bearing area) curves.

2. Experimental Procedure

The experimental investigations were carried out on a universal lathe Pus-1500. The work material was Al6088 aluminum alloy with a diameter of 80 mm, selected to minimize elastic deformation under the penetration force of the ball. The workpiece was clamped in a three-jaw chuck and additionally supported by a tailstock center, which further reduced elastic deformation.

Preliminary machining was performed in the longitudinal direction using a cemented carbide tool with positive cutting geometry. The cutting parameters were a spindle speed of 500 rpm and a feed of 0.2 mm/rev. After preparation, surface plastic deformation was carried out with a specially designed tool for the ball burnishing process. Burnishing was performed using a steel ball of 10 mm diameter at a penetration depth of 0.05 mm.

The aim of the experiments was to investigate the influence of feed rate on the surface quality achieved by ball burnishing. The workpiece length was divided into five cylindrical sections, each 15 mm long. The first section (labeled 0) served as the reference surface and was not subjected to burnishing. Its surface roughness was measured in five zones. The other four sections were burnished with feed rates of 0.05 mm/rev, 0.08 mm/rev, 0.1 mm/rev, and 0.28 mm/rev, respectively (Fig. 1). Roughness measurements were performed in the same way as for the reference section, in five radial zones, using an INSIZE ISR C-002 profilometer.

Fig. 1. Surface of Al6088 workpiece with cylindrical sections treated by ball burnishing under different feed rates

3. Results and Discussion

The results of surface roughness measurements obtained by ball burnishing at different feed rates are presented in Table 1. For each feed, measurements were performed at five circumferential positions (1, 3, 5, 7, and 9) to ensure repeatability. Presented values correspond to the average roughness parameters (Ra and Rz) with standard deviations.

Table 1. Average values of Ra and Rz with standard deviations for different feed rates

Feed rate (mm/rev)	Ra (μm) ± st.dev	Rz (μm) ± st.dev
0.05	1.40 ± 0.15	6.45 ± 0.30
0.08	1.48 ± 0.09	6.80 ± 0.28
0.10	1.62 ± 0.09	7.47 ± 0.71
0.28	1.71 ± 0.06	8.63 ± 1.17
Unburnished	1.77 ± 0.25	8.44 ± 1.19

Fig. 2 and 3 illustrate the relationship between feed rate and the roughness parameters Ra and Rz. A clear decreasing trend is observed as feed decreases. The lowest values are achieved at 0.05 mm/rev, where Ra and Rz are significantly reduced compared to the unburnished reference surface. This confirms that feed rate is the dominant factor in improving surface finish.

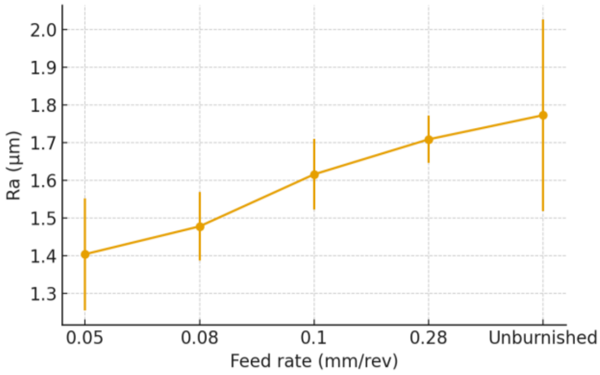

Fig 2. Average Ra values versus feed rate with standard deviation

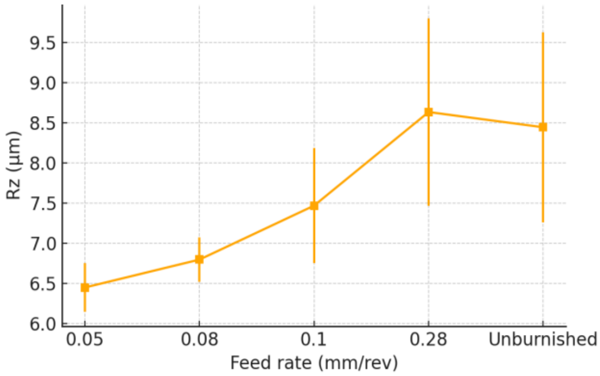

Fig. 3. Average Rz values versus feed rate with standard deviation

In addition to average roughness, Fig. 4 presents the material ratio curves (Abbott-Firestone curves) for all investigated feed rates. The unburnished surface exhibits the steepest slope and highest profile heights, indicating pronounced irregularities. Burnished surfaces, especially at 0.05 mm/rev, show smoother curves and lower Rmax values. This demonstrates an improved load-bearing capacity and higher wear resistance potential, which aligns with the expected benefits of ball burnishing.

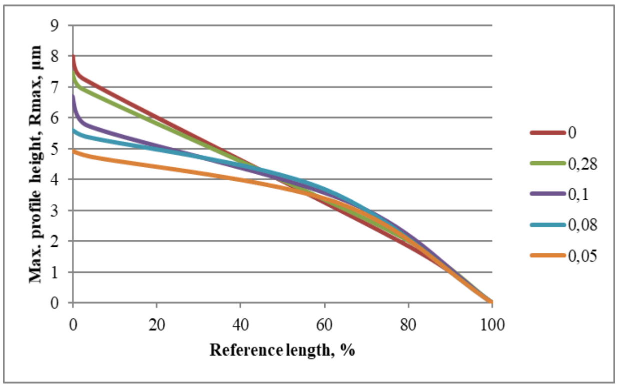

Fig. 4. Material ratio curves (Abbott-Firestone) for different feed rates

The experiments confirm that decreasing the feed rate in ball burnishing significantly improves surface integrity. At the optimal feed of 0.05 mm/rev, the surface roughness parameter Ra was reduced by ~21% compared to the unburnished condition, while Rz decreased by ~24%. Higher feed rates (0.28 mm/rev) provided only slight improvements over the reference surface.

These findings are consistent with the literature, where low feed rates are reported to yield the best surface quality [1, 10]. The improved Abbott-Firestone curves confirm the enhanced functional properties of burnished surfaces, such as increased load-bearing capacity and improved wear resistance [5, 9].

Overall, the obtained results demonstrate that feed rate plays a crucial role in ball burnishing. Lower values (0.05–0.08 mm/rev) should be applied when the goal is to achieve minimal roughness and optimal surface integrity of aluminum alloys

4. Conclusions

This study investigated the influence of feed rate on the surface quality of Al6088 alloy subjected to ball burnishing. Based on the experimental results, the following conclusions can be drawn:

- ✓ Ball burnishing significantly improves surface roughness parameters compared to the unburnished condition.
- ✓ The feed rate was confirmed as the dominant process parameter affecting surface finish.
- ✓ The lowest values of Ra (1.40 μm) and Rz (6.45 μm) were obtained at the feed of 0.05 mm/rev, representing reductions of approximately 21% and 24% compared to the unburnished surface.
- ✓ The Abbott-Firestone (bearing area) curves showed that surfaces treated with lower feed rates have improved load-bearing capacity and reduced profile heights, which enhances their functional performance.
- ✓ The repeatability of measurements at multiple circumferential positions confirmed the reliability of the results.

Overall, the findings indicate that lower feed rates (0.05–0.08 mm/rev) should be applied to achieve optimal surface integrity of aluminum alloys processed by ball burnishing. These results are consistent with previous research and provide a solid basis for further optimization of burnishing parameters in sustainable manufacturing practices.

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References

[1] Asadbeygi, A.; Rezaei, H.; Jalali Aghchai, A. Experimental investigation and optimization of the effect of burnishing process parameters on surface roughness and hardness of Al 2036. In Proceedings of the ASME 2023 International Mechanical Engineering Congress and Exposition, Volume 3: Advanced Manufacturing, New Orleans, Louisiana, USA, 29 Oct–2 Nov 2023; ASME: New York, NY, USA, V003T03A022. https://doi.org/10.1115/IMECE2023-111731

[2] Cagan, S.C. Surface quality and environmental impact analysis of ball burnishing on Al8090 aluminum–lithium alloy. Materials, 2025, 18, 1252. https://doi.org/10.3390/ma18061252

[3] Ferencsik, V.; Varga, G. The influence of diamond burnishing process parameters on surface roughness of low-alloyed aluminium workpieces. Machines, 2022, 10, 564. https://doi.org/10.3390/machines10070564

[4] Yuan, Z.; Zhou, Z.; Jiang, Z.; et al. Evaluation of surface roughness of aluminum alloy in burnishing process based on chaos theory. Chinese Journal of Mechanical Engineering, 2023, 36, 2. https://doi.org/10.1186/s10033-022-00828-8

[5] Özkul, İ. Ball burnishing process effects on surface roughness for Al 6013 alloy. Turkish Journal of Engineering, 2019, 3(1), 9–13. https://doi.org/10.31127/tuje.421135

[6] Dimitrov, D.M. Digital modeling and AI-driven optimization of ball burnishing process parameters. Materials Research Proceedings, 2024. https://doi.org/10.21741/9781644903377-46

[7] Labuda, W.; Wieczorska, A.; Charchalis, A. The influence of the burnishing process on the change in surface hardness, selected surface roughness parameters and the material ratio of the welded joint of aluminum tubes. Materials, 2024, 17, 43. https://doi.org/10.3390/ma17010043

[8] Harish; Shivalingappa, D. The influence of ball and roller burnishing process parameters on surface integrity of Al 2024 alloy. Materials Today: Proceedings, 2020. https://doi.org/10.1016/j.matpr.2020.02.614

[9] Swirad, S. Changes in areal surface textures due to ball burnishing. Materials, 2023, 16, 5904. https://doi.org/10.3390/ma16175904

[10] Amdouni, H.; Bouzaiene, H.; Montagne, A.; et al. Modeling and optimization of a ball-burnished aluminum alloy flat surface with a crossed strategy based on response surface methodology. International Journal of Advanced Manufacturing Technology, 2017, 88, 801–814. https://doi.org/10.1007/s00170-016-8817-8

[11] Tadic, B.; Todorovic, P.M.; Luzanin, O.; et al. Using specially designed high-stiffness burnishing tool to achieve high-quality surface finish. International Journal of Advanced Manufacturing Technology, 2013, 67, 601–611. https://doi.org/10.1007/s00170-012-4508-2

[12] Randjelovic, S.; Tadic, B.; Todorovic, P.M.; et al. Modelling of the ball burnishing process with a high-stiffness tool. International Journal of Advanced Manufacturing Technology, 2015, 81, 1509–1518. https://doi.org/10.1007/s00170-015-7319-4

[13] Babic, M.; Kocovic, V.; Vukelic, D.; Mihajlovic, G.; Eric, M.; Tadic, B. Investigation of ball burnishing processing on mechanical characteristics of wooden elements. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 2016, 231(1), 120–127. https://doi.org/10.1177/0954406216641711

[14] Tadic, B.; Randjelovic, S.; Todorovic, P.; Zivkovic, J.; Kocovic, V.; Budak, I.; Vukelic, D. Using a high-stiffness burnishing tool for increased dimensional and geometrical accuracies of openings. Precision Engineering, 2016, 43, 335–344. https://doi.org/10.1016/j.precisioneng.2015.08.014

[15] Kanovic, Z.; Vukelic, D.; Simunovic, K.; Prica, M.; Saric, T.; Tadic, B.; Simunovic, G. The modelling of surface roughness after the ball burnishing process with a high-stiffness tool by using regression analysis, artificial neural networks, and support vector regression. Metals, 2022, 12(2), 320. https://doi.org/10.3390/met12020320