Advances in Manufacturing Technology XXXVI
A. Thomas et al. (Eds.)

doi:10.3233/ATDE230928

Automatic Process by Turning and Single Roller Burnishing Process on 6063 Al Alloy: Optimization and Implementation

Peerapong Kasuriya[a], Masahiko JIN[b] , and Ukrit Thanasuptawee[c]

[a] *Dept. of Production Technology Education, Faculty of Industrial Education and Technology, King Mongkut's University of Technology Thonburi, Thailand.*
[b] *Dept. of Mechanical Engineering, Faculty of Fundamental Engineering, Nippon Institute of Technology, Saitama, Japan.*
[c] *Faculty of Engineering, Rajamangala University of Technology Lanna, Thailand.*

Abstract. This research studies the feasibility of automatically combining the final turning and roller burnishing processes on Aluminum alloy 6063 (Al6063). Identifying the optimal process parameters yields the desired surface quality. The burnishing process is widely used to enhance the machining quality by improving the surface finish, fatigue layer, and corrosion resistance. this research designed the single roller burnishing tool with spring constant for the final fishing process by automatic tool change on the CNC lathe machine. An important part was conducted experimental design methods to optimize the parameters affecting the burnishing process and implementation. The results showed the parameters affecting the surface roughness after burnishing are feed rate and burnishing force. The implementation of the model prediction can be reduced the surface roughness from 0.365 µmRa to 0.090 ± 0.002µm Ra and 0.927 ± 0.04µmRz. while being able to generate the affected layer of approximately 60 µm.

Keywords. Automatic process of Al6063, single roller burnishing tool, work affected layer, final finishing surface.

1. Introduction

6063 Aluminum alloy (Al6063) is commonly utilized in such applications due to its high strength-to-weight ratio and excellent corrosion resistance. Al6063 mainly contains magnesium (Mg) and silicon (Si) with the strength of the alloy. It provides a good surface finish after machining. The requirements of the high finish surface, it commonly performed on several surface treatment processes after machining. This leads to a long period and a loss of surface texture and dimensional accuracy. In addition, the machining process of the Al6063 shaft cannot achieve the surface finish at the nanometre level and the mirror finishing surface that is lower than 0.1 µm has not been thoroughly addressed and researched in such a typical method.

---

[1] Ukrit Thanasuptawee, t.ukrit@edu.rmutl.ac.th

[2] Peerapong Kasuriya, Peerapong.kas@kmutt.ac.th

Various researchers have attempted to determine the effectiveness of the parameters affecting turning operations on CNC lathes. A surface roughness of 0.36 µm*Ra* was obtained by the automatic turning of Al6063 alloy on CNC lathes using Takushi analysis [1] and the machining of aluminum alloy grades 6063 with tungsten carbide (WC+Co) insert by deep cryogenic treatment gives a surface roughness of 0.373 µm*Ra* with optimal parameters [2]. They demonstrated the effectiveness of the parameters in turning Al6063. The burnishing process is widely used as the super-finishing process to enhance the machining quality by improving the surface finish, fatigue layer, and corrosion resistance. And it is also well known as the plastic formation process. Important mechanistic characteristics of that process. After the machining process, the mechanism presses against the surface at a point (peak to valley) causing a new rearrangement of subsurface structures as a result, it improves surface hardness, which increases the fatigue layer at surface stress points the methods utilized to improve the surface finish at the nano-level.

Numerous studies investigated the controlling constant burnishing force that can be classified into various methods such as the use of hydraulic pressure to apply the burnishing force of hardened steel [3] a hydrostatic burnishing tool affecting residual stress of AISI 8620 steel [4] the burnishing tool uses a constant compression of the spring [5-7] these burnishing tools have been applied to different materials. Due to the use of hydraulic pressure, it is suitable for burnishing in workpieces with high surface hardness. On the other hand, the burnishing tool with spring constant force most are suitable for applications where ductile properties and surface hardness are not very hard materials.

Therefore, this research designed the single roller burnishing tool for the final fishing process by automatic tool change on the CNC lathe machine. An important part was conducted experimental design methods to optimize the parameters affecting the burnishing process and implementation.

2. Experiment procedure

2.1. The single roller burnishing tools.

This experiment aims to design a burnishing tool with spring constant pressure and considered the shapes of the burnishing roller and tip. Previous research studies, it was found that there are many techniques for burnishing tools such as flat-faced roller burnishing tips [8] a ball or sphere diameter of 6 mm [9], and Single toroidal roller burnishing tips [7] etc. In this study, the single toroidal roller burnishing tip was considered due to free rotation during the process. Able to press workpieces having a complex shape, a burnishing tool has been designed as shown in Fig. 1A. The distinctive feature of this tool is during the burnishing process the spring shaft cannot be twisted and rotated while pressing because it was controlled by the spring shaft hole with a guiding groove. A single roller is made from hardened tool steel having a radius of 5 mm installed with a pin bearing inside. The spring compression of the burnishing tool was performed on the compression testing machine as shown in Fig.1B. Three levels of spring stiffness are selected for the burnishing force conditions: 25 N/mm for 50 N, 40 N/mm for 200 N, and 80 N/mm for 350 N respectively.

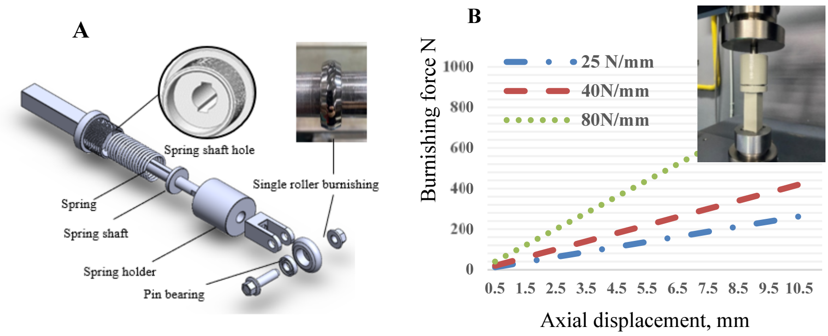

Figure 1. The 3D exploded view of a single roller burnishing tool (A) and spring compression test (B)

2.2. Experimental setup and initial turning conditions.

The experiment was carried out at the CNC lathe machining center (HAAS ST-20L). The roller burnishing tool was installed on automatic tool changers as shown in Fig. 2. This study was performed consisted of 3 main processes: the first is a rough turning process to remove the outer of the workpiece approximately -0.5 mm, the second is finished turning, in which the parameters have been studied in the previously achieved machining of aluminum alloy within 0.373 µm*Ra* which can be applied in this finish turning of Al6063 [1-2]. The turning parameters are a spindle speed of 2500 RPM, feed rate of 0.5 mm/rev and depth of cut of 100 µm with cutting tool insert MITSUBISHI code TNMG160402L-2G NX2525. When the accuracy of 10 pieces was determined, the surface roughness values were 0.365 ± 0.08µm*Ra* and 2.359 ± 0.5µm*Rz*. Therefore, these parameters were chosen as initial turning conditions. And the final process is roller burnishing tool.

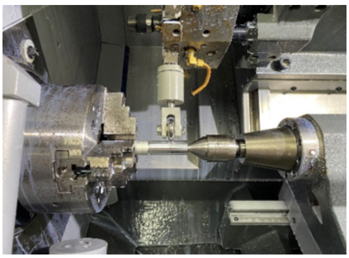

Table 1. The cutting parameters and their levels.

Machining parameter		Low	center	High
Feed rate (mm/rev)	**(A)**	0.001 (-1)	0.005 (0)	0.01 (1)
Spindle speed (RPM)	**(B)**	500 (-1)	1250 (0)	2000 (1)
burnishing force (N)	**(C)**	50 (-1)	200 (0)	350 (1)

Figure 2. The installation of the burnishing tool on the CNC lathe machine.

2.3. Analysis of Variance (ANOVA)

In machining, the influence of spindle speed, feed rate and burnishing force on surface roughness were investigated. The burnishing experiments were conducted based upon the centered of central composite design (CCD) methodology with 2 replications. Thus, total of cutting tests including 40 run orders that were carried out as per design matrix. Furthermore, machining parameters and their levels used for burnishing are shown in Table 1.

3. Experimental results and discussion

3.1. Statistical analysis

we obtained the analysis of variance of surface roughness as shown in table 2. The analysis was performed at significance level of 0.05. Thus, it means factor will be main effect or interaction effect on surface roughness when their term has p-value less than 0.05.

Table 2. Analysis of variance of surface roughness value

Model	0.8305	9	0.0923	38.26	< 0.0001	significant
A-Feed rate	0.0187	1	0.0187	7.74	0.0092	
B-Spindle speed	1.86E-06	1	1.86E-06	0.0008	0.978	
C- Burnishing force	0.4518	1	0.4518	187.36	< 0.0001	
AB	0.0012	1	0.0012	0.4871	0.4906	
AC	0.0123	1	0.0123	5.09	0.0315	
BC	0.0012	1	0.0012	0.5145	0.4787	
A^2	0.032	1	0.032	13.25	0.001	
B^2	0.0003	1	0.0003	0.129	0.722	
C^2	0.1002	1	0.1002	41.55	< 0.0001	
Residual	0.0723	30	0.0024			
Lack of Fit	0.0514	5	0.0103	12.26	< 0.0001	significant
Pure Error	0.021	25	0.0008			
Cor Total	0.9028	39				
R-sq = 91.99% R-sq(adj) = 89.58% R-sq(pred) = 85.94%						

A variance analysis of the surface roughness (Ra) components was made with the objective of analyzing the influence of feed rate, spindle speed, and burnishing force. The main factors significantly influence on the surface roughness were feed rate and burnishing force. Especially, burnishing force has strongest main effect on surface roughness. The interaction effect on the surface roughness were between feed rate and burnishing force. While the square term of feed rate and the square term of burnishing force have the effect on surface roughness. The interaction plots are shown in Fig.3A, illustrate the evolution of the surface roughness.

Figure 3B shows the optimized plot of the burnishing parameters. By adjusting the position of the vertical chain line, variation in the output is evaluated. Which, the optimized values of the burnishing process are feed rate of 0.0056 mm/min, Spindle speed of 2000 RPM and burnishing force of 110.61 N. the optimizer model provides the surface roughness value is 0.0799 µm*Ra*

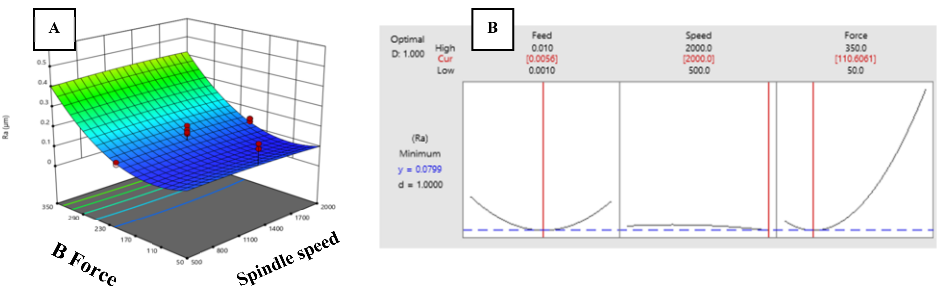

Figure 3. The interaction of burnishing parameters: Feed rate & Burnishing force (A) and the optimize of surface roughness model (B).

3.2. Implementation of the surface roughness obtained by the optimized parameters.

Figure 4A shows a comparison of the two finished surfaces generated by the final turning and the roller burnishing tool, which seen the burnishing process will be smoother than the final turning when observed from the letters reflected on the surface of the workpiece. In addition, when observing the magnified SEM image as shown in Fig. 4B, the surface is smooth without previous machining marks and waviness on the surface. The implementation of this process can be automatically reduced the surface roughness from 0.365 µm to 0.088 µm*Ra* under the conditions of the model prediction at a spindle speed of 2000 RPM, feed rate of 0.005 mm/rev, and burnishing force of 110N as shown in Figure 4C. In addition, the accuracy of 10 pieces, it was found that the surface roughness values were 0.090 ± 0.002µm*Ra* and 0.927 ± 0.04µm*Rz*. And the roundness value of the burnishing process can be reduced from 6.2 ± 1.2 µm to 3.3 ± 0.2 µm due to uniform rolling pressure, resulting in the workpiece being better roundness. The results can be confirmed that the burnishing tool under this model prediction can be used in an application for aluminum Al6063.

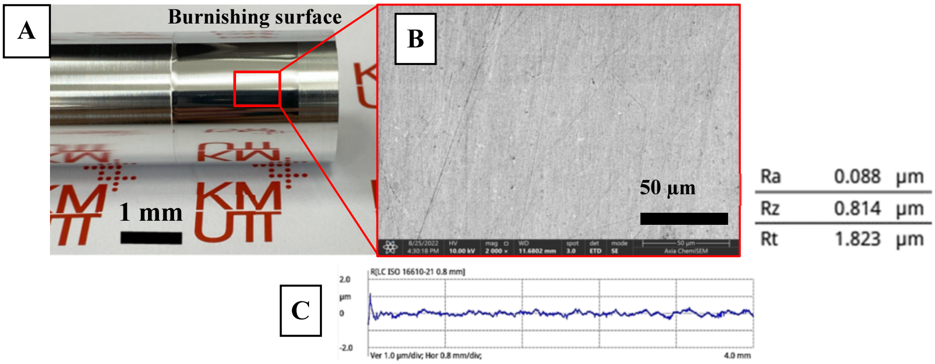

Figure 4. The finished surface of Al6063 by Final turning and burnishing tool (A), the magnified SEM image (B), and the surface roughness of the burnishing process(c)

3.3. Surface cross-section analysis from EBSD and hardness

Figure 5A shows surface cross-section images by EBSD, the subsurface structure after the roller burnishing tool can be seen in the grain on top has a finer size and flattened shape with a depth of approximately 50-70 µm from the edge of a workpiece. which can be assumed that this phenomenon is caused by the roller burnishing force while being able to generate the affected layer. When considering the hardness value as shown in Fig. 5B, it was found that the hardness value from the workpiece edge increased by about 140 HV and gradually decreased until reaching the normal hardness value at 81 HV at a depth of about 60 µm.

4. Conclusion

An automatic combining the final turning and roller burnishing processes on Aluminum alloy 6063 (Al6063) specimens was established through an experimental study. The following conclusions can be made.

- The following ideal single burnishing process parameters were determined using a CCD experiment and model prediction under a minimum roughness: Using a spindle speed of 2000 RPM, a burnishing force of 110 N, and a feed rate of 0.005 mm/rev, the average roughness is expected to Ra =0.0799μm*Ra*.
- The implementation of the model prediction can be reduced the surface roughness from 0.365 μm*Ra* to 0.090 ± 0.002μm*Ra* and 0.927 ± 0.04μm*Rz*.
- The EBSD analysis results confirm the effectiveness of the roller burnishing tool of (Al6063) able to generate the affected layer of 50-70 μm with significant increase the surface hardness on the edge by 72 %

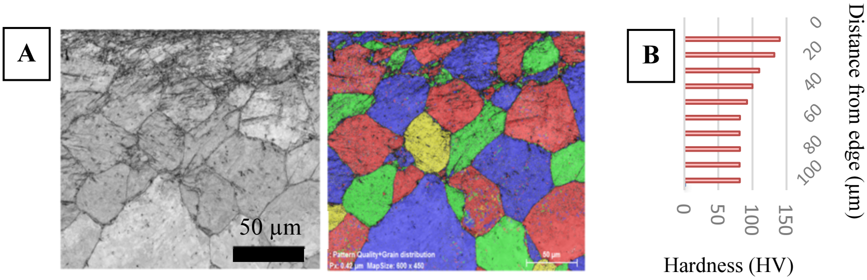

Figure 5. The EBSD image of Al 6063 surface cross-section generated by burnishing tool (A) and Hardness from edge (B)

References

[1] A Saravanakumar, A., Karthikeyan, S. C., Dhamotharan, B., and kumar, V. G. (2018). Optimization of CNC Turning Parameters on Aluminum Alloy 6063 using TaguchiRobust Design. Materials Today: Proceedings 5, (2017), 8290–8298.

[2] Arunkarthikeyan, K.and Balamurugan, K. Studies on the effects of deep cryogenic treated WC–Co inserts on turning of Al6063 using multi-objective optimization. SN Appl. Sci. 2, 2103 (2020). https://doi.org/10.1007/s42452-020-03940-3

[3] Liviu Luca, Sorin Neagu-Ventzel, and IoanMarinescu, Effects of working parameters on surface finish in ball-burnishing of hardened steels, Precision Engineering 29, (2005), 253-256

[4] Abdulaziz J. Alshareef, Ioan D. Marinescu, Ibrahim M. Basudan, Bader M. Alqahtani, and Mohammed Y. Tharwan, Ball-burnishing factors affecting residual stress of AISI 8620 steel, The International Journal of Advanced Manufacturing Technology 107, (2020), 1387–1397

[5] Ramon Jerez-Mesa, Jose Antonio Travieso-Rodriguez, Giovanni Gomez-Gras, Jordi Lluma-Fuentes, Development, characterization and test of an ultrasonic vibration-assisted ball burnishing tool, Journal of Materials Processing Technology 257, (2018), 203-212

[6] V. Jaya Prasad, K. Sam Joshi, V.S.N. Venkata Ramana, and R. Chiranjeevi, Effect of Roller Burnishing on Surface Properties of Wrought AA6063 Aluminium Alloys, Material today proceeding 5, Issue 2, Part 2, (2018), 8033-8040

[7] G.V.Duncheva, J. T. Maximov, V. P. Dunchev, A. P. Anchev, T. P. Atanasov and Jiri Capek, Single toroidal roller burnishing of 2024-T3 Al alloy implemented as mixed burnishing process, The International Journal of Advanced Manufacturing Technology 111, (2020), 3559–3570

[8] Samuel José Casarin, Luiz Eduardo De Angelo Sanchez, Eduardo Carlos, Bianchi, Vicente Luiz Scalon, Renan Luis Fragelli, Eduardo Luiz De Godoi, and Maria Da Penha Cindra Fonseca, Effect of burnishing on Inconel 718 workpiece surface heated by infrared radiation, Materials and Manufacturing Processes, V.48, (2021), 1853-1864

[9] M.R. StalinJohn, A. WelsoonWilson, A. Prasad Bhardwaj, Avinav Abraham, and B.K. Vinayagam, An investigation of ball burnishing process on CNC lathe using finite element analysis, Simulation Modelling Practice and Theory 62, (2016), 88-101