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Modeling and optimization of roller burnishing of Al6061-T6 process for minimum surface roughness, better microhardness and roundness

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ABSTRACT

Introduction. Roller burnishing is one of the most common methods of improving the surface quality of parts, wear resistance, microhardness, and corrosion resistance. The process involves compressing and smoothing the workpiece using the pressure of a hardened roller. It is often used to improve part performance and lifespan in sectors including automotive, aerospace, and medical equipment manufacturing. The literature reviewed shows that the roller burnishing process effectively improves the overall surface quality and hardness of the workpiece. In addition, roller burnishing is considered as an affordable method to enhance the functionality and robustness of machined parts by reducing the likelihood of surface defects such as like scratches and cracks. However, very few studies have been reported on the modeling and optimization of roller burnishing of *Al6061-T6* for minimum surface roughness, better microhardness, and roundness. **The methods of investigation.** In the current work, roller burnishing of *Al6061-T6* is modeled and optimized for superior microhardness, roundness, and minimal surface roughness. Under dry-cutting conditions, the performance of roller burnishing of *Al6061* specimens is assessed in terms of process factors such as cutting speed, feed, and number of passes. Mathematical models to predict the surface roughness, microhardness, and deviation in roundness are developed based on the experimental results. **Results and Discussion.** The coefficient of correlation for the developed models is found to be close to 0.9, which indicates that it can be reliably used to predict and optimize the roller burnishing of the *Al6061-T6*. According to this study, the use of the following cutting parameters leads to the lowest variation in roundness (4.282 µm), the better microhardness (119.2 Hv), and the lowest surface roughness (0.802 µm): cutting speed 344 rpm, feed 0.25 mm/rpm and four passes. Further, the study reveals that increasing the number of passes (beyond four) does not significantly improve the surface roughness or microhardness. However, it does lead to a slight increase in the roundness deviation. Therefore, in order to achieve optimal results, it is recommended to use a maximum of four passes during roller burnishing of *Al6061* specimens under dry cutting conditions. These results imply that roller burnishing can effectively improve the overall quality and hardness of the workpiece surface. In addition, roller burnishing is considered as an affordable method to increase the functionality and robustness of machined parts by reducing the likelihood of surface defects like scratches and cracks.

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Introduction

The surface quality of parts created by various metal forming and machining processes is improved using traditional chip removal techniques like grinding, lapping, and shaving. However, research is still being conducted to find new ways to produce parts in a single process and find new ways to produce parts in one process and eliminate secondary finishing procedures. This is because higher finishing quality standards, lower production costs and shorter production times improve competitiveness.

One of the most widely used techniques is the burnishing procedure, which is carried out on a variety of metal workpieces using roller and ball forms. Burnishing is a process that smooths out surface defects on a

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metal, enhancing its shine and durability, and is commonly used in industries such as automotive, aerospace, and jewelry manufacturing. The burnishing procedure improves the surface quality of the workpiece quality on a microscopic level without causing chipping. This is a typical finishing technique used on milling or lathe machines to improve surface quality, wear resistance, microhardness, and corrosion resistance [1]. As a result, it is essential to achieve a high level of surface quality after burnishing [2].

When combined with machine feed, the polishing stress exceeding the yield strength distorts the micro-scale peaks of the surface and fills the valleys along the polished length [3–4]. Polished materials acquire a more defined external shape due to plastic deformation, which is facilitated by the continuous action of the polishing tool on the surface of the workpiece. It has been laid out that the force applied to the workpiece and the number of passes made during the polishing operation are directly related to the hardness of the workpiece. This strategy is usually performed without the use of any lubricants. Various polishing process parameters, including the kind of polishing interaction, number of passes, the speed and the polishing depth have been the subject of various studies [5–6].

By combining the roller burnishing and electrochemical turning processes, *Ebeid* and *Ei-Taweel* [7] investigated surface harshness and material removal rate enhancement in machining *Al-Zn-Mg* alloy. The information boundaries were examined, utilizing the *Taguchi* strategy to decide the best qualities. *Luo et al.* [8] investigated the effects of feed, speed, and entry depth of penetration on the forming power in a machine on metal *H62* and *Al*-composite *LY12* utilizing a polycrystalline precious stone device. The results showed that the polishing force was most impacted by factors like depth of penetration, feed, and speed.

One of the advancements in the burnishing is the simultaneous utilization of rolling and sliding motions to improve the surface nature of round and hollow metal workpieces made of *ASTM 2017* and *ASTM 1055*. The effects of depth of penetration, feed, and speed on this strategy were also different for different workpiece materials [9]. Roller polishing was used by *Sundararajan* and *Nagarajan* [10] to improve the surface qualities of the steel *EN8* workpiece. The burnishing was carried out at shaft speeds ranging from 100 to 2,700 rpm and at a constant feed rate. The analysis of the surface roughness and hardness of steel *C40E* during the burnishing was evaluated by *Kumar et al.* [11]. The burnishing parameters were speed, feed, entry depth of penetration, and number of passes.

Przybylski [12] performed machining, followed by burnishing. His study showed that performing burnishing immediately after machining on the same machine reduces assembly time and eliminates additional finishing operations. *Shirsat et al.* [13] investigated the parametric effect of force, speed, feed, workpiece width, and ball dimensions on the surface of a metal material after burnishing. The *SAE 20*, *30*, *40*, and *SAE 50* oils were utilized in the study. Their study showed that using *SAE 30* oil provided the best surface quality and the force applied to the workpiece during burnishing had the greatest effect on the finished surface compared to other process parameters considered in the study. In a roller burnishing cycle for a *TA2* workpiece, *Yuan et al.* [14] presented an original technique for selecting the ideal polishing boundaries, such as speed, feed, and entry depth of penetration. The boundaries obtained as a result of the modelling reflect the surface irregularities and microhardness of the outer layer of the resulting workpiece. Various studies have been conducted within the framework of this classification [15–16].

Cobanoglu and *Ozturk* [17] investigated the surface quality and microhardness of *AISI 1040* carbon steel during the roller polishing process. The parameters for the burnishing were speed, feed, and polishing force. The trial levels were performed using the *Taguchi* technique. An *ANOVA* investigation was utilized to determine the effect of each process parameter on surface and microhardness. The study revealed that the feed rate significantly affects the surface quality in the roller polishing process. Several studies have shown that the developed polishing system increases the service life of metal products and their wear resistance [18–19].

From the reviewed literature, it is found that the roller burnishing process efficiently improves the overall surface quality and hardness of the workpiece. In addition, roller burnishing is considered as an affordable method to enhance the functionality and robustness of machined parts by reducing the occurrence of surface defects such as scratches and cracks. However, very few studies have been reported on the modeling and optimization of roller burnishing of *Al6061-T6* alloy to obtain the lowest surface roughness, best microhardness and roundness. With this view, in this study, roller burnishing was carried out on the *Al6061-T6* alloy workpiece to model and optimize the process to obtain high microhardness, lowest roundness deviation and lowest surface roughness. The roller burnishing of *Al6061* alloy specimens was evaluated under dry-cutting conditions, considering factors like cutting speed, feed, and number of passes. Mathematical models to predict the surface roughness, microhardness, and deviation in roundness were developed based on the experimental results.

Materials and Design

The aluminum alloy *6061* (*Al6061-T6*), which is widely used in general purpose applications, is used in this investigation. This alloy is renowned for its strength-to-weight ratio, corrosion resistance, and weldability, making it suitable for various structural components and popular in manufacturing processes. It is a precipitation hardening aluminum alloy. Magnesium and silicon are the two most important constituents. The main advantage of aluminum *6061* is its weldability. The selected specimen had a diameter of 30 mm, a length of 160 mm. The length of each machined surface was 50 mm. This representative part is very common in aircraft structures. The properties and chemical composition of *6061* aluminum alloy are shown in Table 1.

Table 1

Chemical composition of *Al6061-T6* alloy

Element	*Al*	*Cu*	*Cr*	*Mg*	*Mn*	*Si*	*Zn*	*Fe*	*Ti*
Amount (wt. %)	95.8	0.15	0.2	1.1	0.15	0.75	0.25	0.19	0.15

Single roller burnishing tool with a carbide roller was used in the present study. The carbide roller is spring-loaded in the two axial directions to provide the required pressure during the burnishing operation. The worn-out carbide roller can be restored by regrinding/lapping, which will prolong the tool life. The tool with carbide roller is suitable for all outside surfaces of shafts, tapered shaft, radii, shoulders etc. and can be used on *CNC* lathes, turret or conventional lathes. The turned surface can be burnished up to 0.1 to 0.2 μm. Roller burnishing tool used in the present study is shown in Fig. 1.

The experiments were carried out by varying the feed, cutting speed, and number of passes and at a constant depth of penetration of 0.5 mm. A design of experiment approach (*DOE*) was used to understand critical factors promoting consequences on sustainability indicators (surface roughness, microhardness, and roundness error). Central composite design (*CCD*) was used to develop empirical models and analysis of all responses. Central composite rotatable design (*CCRD*) test matrix with an alpha value of 1.6817 was used for the design of experiments. Each numeric parameter was varied at five levels: plus, and minus alpha (axial points), plus and minus 1 (factorial points) and the center point. In this study, twenty roller burnishing experiments were performed varying with the process parameters to develop a surface roughness, microhardness, and roundness error models. The coded levels and corresponding actual values of cutting parameters are given in Table 2.

Fig. 1. Roller burnishing tool used in the present study

Table 2

Coded levels and corresponding actual cutting parameters

Parameters	Levels for alpha value equal to				
	−1.6817	−1	0	+1	+1.6817
Cutting speed (*V*) (rpm)	100	200	300	400	500
Feed (*f*) (mm/rev)	0.1	0.15	0.2	0.25	0.3
Number of passes (*N*) (mm)	0.5	1	1.5	2	2.5
Depth of penetration (mm)	0.5				

Average surface roughness values were measured using a *Taylor Hobson Talysurf* stand-alone surface roughness measuring device on a *Surtronic Duo*. The surface roughness was measured at three equally spaced points around the circumference of the workpiece to obtain the statistically significant value. Roundness deviation was measured using *Bridge type CMM* (Make: Zeiss, Model: Contura, Range: 1200×800×800 mm). The geometrical deviations were obtained by measuring the roundness in twelve sections of the calibrated area using a millesimal dial gauge with a measuring range of 12.5 mm, a scale division of 0.001 mm and a maximum permissible error (*MPE*) of 4 µm. Microhardness was measured by the *Vickers* microhardness tester using a diamond indenter with an angle of 136°, a load of 100 g, and a dwell time of 20 sec.

Results and Discussion

In this section, the effect of the roller burnishing process parameters on the process responses is discussed based on the developed regression equations. Curves showing the various responses are plotted by varying one of the input parameters and keeping the other parameters constant to understand the physics of the process and the influence of the cutting parameters on different responses. The contribution of cutting parameters on different responses are also obtained. Finally, a desirability function approach is addressed for optimization of process responses in roller burnishing of *Al6061-T6* alloy.

Experiments were carried out varying the cutting speed, feed, and the number of passes (*Input parameters*). The experimental matrix and results of surface roughness, microhardness, and maximum roundness deviation (roundness error) in roller burnishing *Al6061-T6* alloy are shown in Table 3.

$$Ra = 0,9734 + 3,38068 \cdot 10^{-4} V - 2,7693 f + 0,0563 N - 3,25 \cdot 10^{-3} Vf -$$
$$- 4,125 \cdot 10^{-4} VN - 0,425 fN + 2,6136 \cdot 10^{-6} V^2 + 12,9545 f^2 + 0,02113 N^2; \quad (1)$$

$$HV = 119,534 + 0,2611 V - 233,0681 f - 12,0056 N - 0,425 Vf - 0,0187 VN + 42,5 fN -$$
$$2,3636 \cdot 10^{-4} V^2 + 604,5454 f^2 + 1,6363 N^2; \quad (2)$$

$$Re = -9,525 + 0,01281 V + 157,125 f + 3,3937 N + 0,0925 Vf - 0,0203 VN + 18,25 fN +$$
$$+ 2,125 \cdot 10^{-5} V^2 - 610 f^2 - 0,375 N^2. \quad (3)$$

The adequacy of the developed equations was checked by Analysis of Variance (*ANOVA*). *R*-Squared is a coefficient of multiple determinations, which measures variation proportion in the data points. It is always desirable for the correlation coefficient (*R*-Squared) to be in the range of –1 to +1. The equation makes sense if the value of *R* is very close to +1. The Adjusted *R*-Squared is a measure of the degree of deviation from the mean explained by the model. Predicted *R*-squared is a measure of how well the model predicts the response value. Adjusted and predicted *R*-Squared values should differ from each other by approximately 0.20 to ensure a “reasonable agreement”. If they are not, there may be a problem with either the data or

Table 3

Roller burnishing experimental matrix

Cutting speed (V) (rpm)	Feed (f) (mm/rev)	No. of passes	Surface roughness (Ra) (μm)	Microhardness (HV)	Roundness error (Re) (μm)
300	0.2	3	0.81	117	7.7
200	0.15	2	0.82	114	9.6
200	0.15	4	0.89	116	8.6
200	0.25	2	0.92	116	5.4
200	0.25	4	0.9	125	8.7
400	0.15	2	0.94	118	10.1
400	0.15	4	0.84	111	1.6
400	0.25	2	0.97	110	8.4
400	0.25	4	0.79	113	2.9
300	0.2	3	0.81	117	8.4
300	0.2	3	0.81	117	8.6
100	0.2	3	0.92	112	13.2
500	0.2	3	0.93	104	4.2
300	0.1	3	0.94	123	1.5
300	0.3	3	0.96	124	2
300	0.2	1	0.95	123	8.7
300	0.2	5	0.86	125	4
300	0.2	3	0.83	117	6.9
300	0.2	3	0.82	113	8.3
300	0.2	3	0.81	118	8.7

the model. Adequate precision is a measure of the range in predicted response about its associated error, in other words a signal-to-noise ratio. Its desired value is 4 or more.

The *ANOVA* results for surface roughness, microhardness, and roundness error when roller burnishing a workpiece is given in Table 4. *ANOVA* results for surface roughness show, that the model *F*-value is 46.91 which implies that the model is significant. The "*Prob > F*" values less than 0.0500 that the model terms are significant. In this case $\boldsymbol{f}$, $\boldsymbol{N}$, $\boldsymbol{V\times f}$, $\boldsymbol{V\times N}$, $\boldsymbol{f\times N}$, $\boldsymbol{V_2}$, $\boldsymbol{f_2}$, $\boldsymbol{N_2}$ are the significant model terms. The *ANOVA* results for microhardness show that the model *F* value is 11.99, which means the model is significant. The probability that such a large "Model *F*-Value" could be caused by noise is only 0.03 %. In this case, $\boldsymbol{V}$, $\boldsymbol{V\times f}$, $\boldsymbol{V\times N}$, $\boldsymbol{f\times N}$, $\boldsymbol{V_2}$, $\boldsymbol{f_2}$, $\boldsymbol{N_2}$ are the significant model terms. The results of microhardness analysis obtained by *ANOVA* show that the "Model *F*-Value" of 17.62, which means that the model is significant. In this case, $\boldsymbol{V}$, $\boldsymbol{N}$, $\boldsymbol{V\times N}$, $\boldsymbol{f\times N}$, $\boldsymbol{f_2}$ are significant model terms.

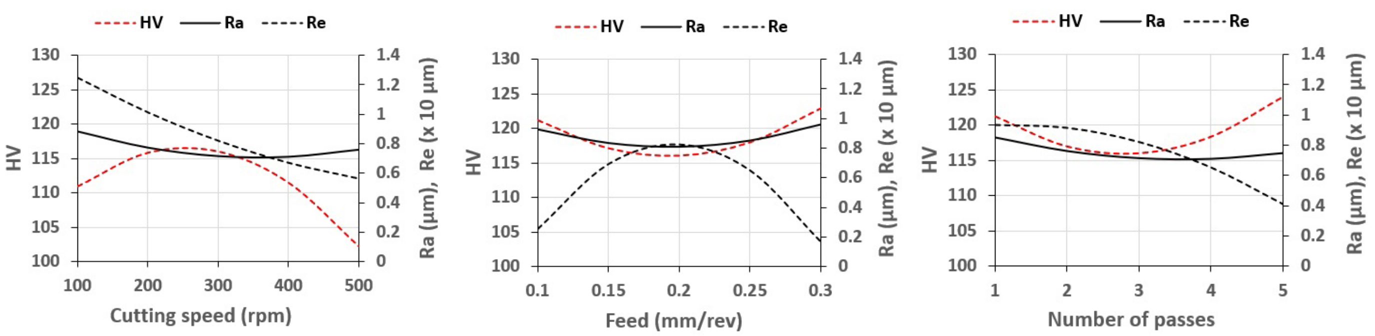
The *R*-squared values, which measure the variation proportion in the data points, are above 0.9 for all the developed models. Therefore, the developed empirical equations are reliable to predict the surface roughness, microhardness, error in roundness during the roller burnishing of *Al6061-T6* alloy (Eq. 1 to 3).

For better understanding, two-dimensional (2-*D*) plots are plotted by varying the cutting speed, feed, and number of passes using the developed Eq. 1 to 3, respectively. Curves showing the surface roughness, microhardness, and roundness error are plotted by varying one of the input parameters and keeping the other parameters constant. Fig. 2*a* shows the change of the measured characteristics as a function of the cutting speed plotted using a feed value of 0.2 mm/rev and three passes. It can be seen that surface roughness decreases with an increase in the cutting speed up to 360–380 rpm and then increases. Microhardness can be seen as increasing with the cutting speed. However, there is an optimum, and it can be regarded as

Table 4

***ANOVA* for surface roughness, microhardness, and roundness**

Factors	Surface roughness (R_a)	Microhardness (*HV*)	Roundness error *(Re)*
R-squared	0.9769	0.9152	0.9407
Adj. *R*-Squared	0.956	0.8389	0.8873
Pred. *R*-Squared	0.8472	0.855	0.8933
Adeq. Precision	19.328	15.464	16.002
Model *F*-value	46.91	11.99	17.62



a *b* *c*

Fig. 2. Responses varying with (*a*) Cutting sped, (*b*) Feed, and (*c*) Number of passes

decreasing when the cutting speed exceeds 280–300 rpm. On the other hand, roundness error can be seen as decreasing with an increase in the cutting speed.

Fig. 2*b* depicts the variation of measured responses varying with feed, plotted using cutting speed of 300 rpm and three passes. And Fig. 2*c* depicts the variation of measured responses depending on the number of passes, plotted using a cutting speed value 300 rpm and feed rate of 0.2 mm/rev.

From Fig. 2*b*, the optimum values for the feed-dependent responses can be seen. The minimum surface roughness and roundness error can be obtained using feed in the range of 0.18–0.22 mm/rev, a cutting speed of 300 rpm, and three passes. However, maximum microhardness can be obtained using higher feed values. When the feed is increased to 0.2 mm/rev, a decrease in surface roughness and microhardness can be observed, as well as an increase in the roundness deviation. However, these responses can be seen as changing its trends beyond the feed value of 0.2 mm/rev.

The minimum roundness error and maximum microhardness can be obtained by using either of lower or higher feed values. However, minimum surface roughness can be obtained using feed value in the range of 0.18–0.22 mm/rev. Surface roughness can be seen as decreasing with an increase in number of passes. However, no significant benefit in lowering surface roughness can be seen beyond using four number of passes. Roundness error can be minimized using higher number of passes. Similarly, a maximum microhardness can be obtained using higher number of passes.

The *ANOVA* results for the ***F***-values of surface roughness, microhardness, and roundness error are shown in Table 5. The factors that had a significant effect on the results are underlined. Similarly, percentage contributions of different elements, obtained by dividing the corresponding element ***F***-value by the total ***F***-value, are also given in Table 5. It can be seen that, surface roughness is mainly affected by the higher feed rate (almost 30.76 %), followed by higher cutting speed and interaction effects of the cutting speed and the number of passes (nearly 20 % and 15.88 %, respectively), and the cutting speed and the feed have little effect. However, it can be considered that the number of passes has a great effect on reducing the surface roughness. The percentage contributions of these significant model terms are shown in bold-case in Table 5.

Table 5

***ANOVA* for *F*-values and % contribution of different parameters**

Elements	Surface roughness (R_a)		Microhardness (H_V)		Roundness error (*Re*)	
	F-Values	*% contri-bution*	*F*-Values	*% contri-bution*	*F*-Values	*% contri-bution*
Cutting speed *(V)* (m/min)	0.3382	0.07	<u>15.8251</u>	**16.91**	<u>40.2758</u>	**25.89**
Feed *(f)* (mm/rev)	6.3512	1.23	0.6335	0.68	0.6619	0.43
Number of passes *(N)*	<u>63.1738</u>	**12.25**	1.5631	1.67	<u>24.0589</u>	**15.47**
Interaction $V \times f$	<u>12.7024</u>	2.46	7.4668	7.98	1.4796	0.95
Interaction $V \times N$	<u>81.8517</u>	**15.88**	5.8132	6.21	<u>28.7154</u>	**18.46**
Interaction $f \times N$	<u>21.7218</u>	4.21	7.4668	7.98	5.7595	3.70
V^2	<u>103.2749</u>	**20.03**	<u>29.0338</u>	**31.02**	0.9816	0.63
f^2	<u>158.5728</u>	**30.76**	<u>11.8708</u>	**12.68**	<u>50.5574</u>	**32.50**
N^2	<u>67.5406</u>	**13.10**	<u>13.9156</u>	**14.87**	3.0571	1.97
Total *F*-value	515.5274	100	93.5887	100	155.5472	100

* Significant elements are shown as underlined and contributions in bold-case.

As for microhardness, cutting speed and elements in an interaction effects, the higher order effects and elements can be considered significant depending on the feed rate and the number of passes. It can be seen that the microhardness is mostly affected by the higher cutting speed (almost 31.02 %), followed by the cutting speed (almost 16.91 %) and the higher number of passes and feed rate (almost 14.87 % and 12.68 %, respectively), while the feed rate and the number of passes have almost no effect (Table 5). The roundness error is significantly affected by the higher order of feed rate (almost 32.5 %), followed by the cutting speed (almost 25.89 %), and the combined effect of the cutting speed and the number of passes (almost 18.46 %) and the number of passes (almost 15.47 %).

It can be seen that the number of passes significantly affects the surface roughness, and the cutting speed significantly affects the microhardness and roundness error. It can be seen from Fig. 2 and Table 5 that the tolerances are inherently in conflict with the process parameters. And to obtain positive results, multi-objective optimization of these conflicting parameters is required.

In the present work, the roller burnishing process parameters are optimized using the desirability function approach to obtain the minimum surface roughness, maximum microhardness, and minimum roundness error. In this approach, each response variable is transformed into a desirability function, and the optimization of several response variables is transformed into the optimization of a single desirability function [20–22]. The process variables and the range of response functions are given in Table 6.

The minimum and maximum limits of surface roughness, microhardness and roundness error are referred to from experimental observations as depicted in Table 6. Each response is transformed into its respective desirability function by using a one-way transformation [16]. In the present study, the multi-objective optimization of roller burnishing was performed using optimization module of the *Design-Expert*® software. For the optimization study, around 100 data points having different combinations of process parameters were considered within the range shown in Table 6. For each level of independent parameters, the desirability for surface roughness, desirability for microhardness, and desirability for roundness error were calculated. Then, a single desirability function, desirability for minimum surface roughness, maximum microhardness, and minimum roundness error was calculated. Table 7 shows the optimized process parameters for minimum surface roughness, maximum microhardness, and minimum

Table 6

Constraints for optimization of process parameters

Parameters	Goal	Min.limit	Max.limit
Cutting speed, *V* (rpm)	Is in range	100	500
Feed, *f* (mm/rev)	Is in range	0.1	0.2
Number of passes, *N* (mm)	Is in range	1	5
Surface roughness (R_a)	Minimize	0.79	0.97
Microhardness (*HV*)	Minimize	104	125
Roundness error (*Re*)	Minimize	1.5	13.2

Table 7

A family of optimized process parameters

Sr. No.	Cutting speed (*V*) (rpm)	Feed (*f*) (mm/rev)	No. of passes	Surface roughness (*Ra*) (μm)	Microhardness (*HV*)	Roundness error (*Re*) (μm)	Desirability
1	344.48	0.25	4	0.807	119.2	4.282	0.7927
2	342.62	0.25	4	0.808	119.3	4.340	0.7926
3	348.05	0.25	4	0.806	118.9	4.172	0.7925
4	347.97	0.25	4	0.805	118.8	4.206	0.7914
5	355.29	0.25	4	0.804	118.2	3.950	0.7909
6	343.96	0.25	4	0.806	119.1	4.359	0.7906
7	345.53	0.25	3.99	0.807	119.1	4.273	0.7905
8	348.67	0.25	3.98	0.806	118.7	4.195	0.7886
9	344.31	0.25	3.97	0.808	119.1	4.346	0.7872
10	335.65	0.24	4	0.805	119.3	4.781	0.7835
11	336.95	0.25	3.94	0.811	119.5	4.623	0.7816
12	342.96	0.25	3.93	0.809	118.9	4.465	0.7799
13	308.15	0.24	4	0.815	121.1	5.762	0.7627
14	315.59	0.25	3.87	0.820	120.6	5.374	0.7610
15	336.65	0.2	4	0.795	116.6	5.236	0.7350
16	349.45	0.15	4	0.840	115.6	2.645	0.7111
17	359.16	0.16	4	0.838	115.1	2.346	0.7102

roundness error. The solution having the highest desirability level was selected as an optimum parameter and as shown in Table 7.

In the present investigation, it is found that the cutting speed of 344 rpm, the feed rate of 0.25 mm/rev, and four passes are the optimum parameters for roller burnishing of *Al6061-T6* for obtaining the minimum surface roughness of 0.807 μm, the maximum microhardness of 119.2 HV, and the minimum roundness error of 4.282 μm. Based on the experimental observations and optimization studies, this study finds that the roller burnishing is the better option for obtaining better geometry of *Al6061-T6* alloy part. However, this study points out that the further research is required on roller burnishing of *Al6061-T6* alloys using different cooling techniques to obtain improved machined surface geometry with the surface roughness approaching 0.3–0.4 μm and higher microhardness

Conclusions

In this paper, an attempt was made to investigate the roller burnishing process of *Al6061-T6* alloy. The following conclusions can be drawn:

The surface roughness decreases with the increase in the cutting speed up to 360–380 rpm and then increased. Microhardness increases with the cutting speed. However, it has a certain optimum and when the cutting speed reaches 280–300 rpm, the microhardness decreases. On the other hand, the roundness error decreases with the increase in the cutting speed.

The minimum error in surface roughness and roundness is obtained at feed values in the range of 0.18–0.22 mm/rev, a cutting speed of 300 rpm and three passes. However, the maximum microhardness is obtained at higher feed values. A decrease in surface roughness and microhardness, as well as an increase in the error in determining roundness are noted with an increase in the feed value to 0.2 mm/rev. However, it is noted that with an increase in the feed value to 0.2 mm/rev, these responses change for the better.

The minimum roundness error and maximum microhardness are obtained using either of lower or higher feed values. However, the minimum surface roughness is obtained using a feed value in the range of 0.18–0.22 mm/rev. It is noted that the surface roughness decreases with an increase in the number of passes. However, no significant improvement in reducing the surface roughness is found after four passes. The deviation from roundness is minimized with an increase in the number of passes. And the maximum microhardness is obtained with an increase in the number of passes.

The surface roughness is mostly affected by higher feed rate (nearly 30.76 %), followed by higher cutting speed and the interaction effect of cutting speed and number of passes (nearly 20 % and 15.88 %, respectively), while cutting speed and feed rate have little effect. However, the number of passes is found to be significant in reducing the surface roughness.

The microhardness is mostly affected by higher cutting speed (nearly 31.02 %), followed by cutting speed (almost 16.91 %) and the number of passes and feed rate (nearly 14.87 % and 12.68 %, respectively), while feed rate and number of passes have little effect (Table 5). It is found that the roundness deviation is significantly affected by the higher feed rate (nearly 32.5 %), followed by the cutting speed (nearly 25.89 %), the interaction effect of the cutting speed and the number of passes (nearly 18.46 %), and the number of passes (nearly 15.47 %).

The cutting speed of 344 rpm, feed rate of 0.25 mm/rev, and four passes are found as the optimal parameters for roller burnishing of *Al6061-T6,* which can obtain the minimum surface roughness of 0.807 μm, the maximum microhardness of 119.2 HV, and the minimum roundness error of 4.282 μm.

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Conflicts of Interest

The authors declare no conflict of interest.