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Influence of the effect of the ball burnishing process applied to Al 7075-T6 alloy in different nano-aluminum powder-added grease environment on surface quality

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Abstract

Surface roughness is a very important factor in determining the quality of the product to be obtained, as it affects the production cost and performance of mechanical parts. Surface quality is considered primarily as a design parameter for determining functional properties such as corrosion resistance and fatigue strength of the part. Therefore, this study aims to improve the surface roughness of Al 7075-T6 material, which is generally used in aerospace and defense industries. In addition, Al 7075-T6 alloy is an aluminum alloy used in parts that require high strength in the military and aircraft industry, automotive industry, and nuclear applications. To increase the surface quality of the parts, a ball burnishing apparatus was designed and experiments were carried out by determining four different force parameters. At the same time, the forces were completed in environments where different ratios (0, 1, 3, 5, and 10% by weight) of nano-Al powders were added to the grease. Thanks to these powders, it is aimed to increase the quality of the surface of the ball burnishing Al 7075-T6 alloy. Ball burnishing is a simple, fast, and inexpensive surface improvement process that is used to remove irregularities on the surfaces of materials after processing. This method is a known method of mechanical surface treatment to impart certain physical, mechanical, and tribological properties to the workpiece. This process is based on the principle of burnishing the workpiece with an apparatus to remove the irregularities on the surface by plastic deformation. As a result of the experiment, the effect of each parameter on the surface quality of the Al-7075-T6 alloy was investigated. Thus, the most suitable test parameters affecting the surface quality of Al-7075-T6 alloy were determined.

1. Introduction

Aluminum and its alloys are widely used in industry due to their lightweight, strength, and easy forming capabilities [1-3]. Aluminum alloys play an important role in the development of aviation, space, automotive, military, and defense industries due to their lightweight (density 2.81 g/cm^3) as well as their mechanical properties [4-6]. Among these alloys, the importance and application areas of 7075-T6 quality aluminum alloys are increasing, especially in the defense and aerospace industry [7].

Surface roughness is important in determining the quality of the product to be obtained, as it affects the mechanical properties, performance, and production cost of mechanical parts [8, 9]. Characteristic irregularities occur on the surface of the workpiece after many machining operations [10]. Ball burnishing is a simple, fast, and inexpensive process used to eliminate these irregularities [11]. This process is a well-known mechanical surface treatment method to give the workpiece certain physical, mechanical and tribological properties [12]. This process is based on the principle of compressing by applying an apparatus to obtain a smooth surface by removing irregularities on the surface by plastic deformation [13]. As a result, this process involves turning, milling, honing, grinding, etc. It can be used in place of other traditional surface treatment techniques.

The parameters affecting the surface quality of the workpiece when the ball burnishing process is applied are workpiece materials, ball materials, ball types, burnishing forces, number of passes, physical properties of the ball (hardness, ball size, etc.), lubricants, feed rates and burnishing speed. When the literature is searched, it is seen that the researchers studied different materials and burnishing process parameters (force, speed, passes, etc.) [14-20]. Studies on the application of ball burnishing under different environmental conditions are limited in the literature, and it is still an issue that needs to be developed. This experimental study aims to obtain optimum surface roughness values of aluminum alloy (Al7075-T6) in different burnishing forces and burnishing environments.

2. Method

The experiments were carried out using the Al 7075-T6 aluminum solid bar. The chemical content of Al 7075-T6 used as a workpiece is shown in Table 1. The dimensions of this workpiece material are Ø50 x 280 mm and a total of twenty tests have been carried out using two of them. Each workpiece is divided into ten equal parts. Different parameters have been applied to each part.

Table 1. Chemical content (wt.%) of Al 7075-T6 aluminum alloy

Workpiece	Al	Cu	Fe	Mg	Si	Mn	Ti	Zn	Cr
Al7075-T6	Balance	1.94	0.45	2.71	0.37	0.25	0.19	5.63	0.21

The experiments were carried out on a conventional lathe as shown in Figure 1. The Al 7075-T6 workpiece was first turned at 400 rpm to make the surface suitable for testing, and then the surface roughness value was measured. The surface roughness value (Ra) obtained without any processing is 1.558 m. The experiments were done with a conventional lathe. In addition, using a force gauge, the force parameter used for ball burnishing was accurately determined (Figure 1). The force meter is calibrated every three months. Particle penetration between the ball burnishing apparatus and the contact surface is prevented. This is because anything entering between the interface between the apparatus and the sample adversely affects the quality of the surface. While planning the experimental design, twenty tests were conducted using four different burnishing forces (50, 100, 150, 200N) and five different environments (pure Al, grease with 1%, 3%, 5%, and 10% nano-Al powder additive) (Table 2). 1, 3, 5 and 10 wt % Al powders of nano-size were added into the grease and mixed (Figure 2).

Surface roughness is used as a measure in determining the surface texture of the material [1]. After any test procedure applied to the workpiece, changes in the surface topography of the material occur at the micron level [21]. Determining these changes is very important in terms of the mechanical properties of the part. Since surface roughness helps to determine the performance of any mechanical component with strategic definition, it provides the opportunity to predict the irregularities that may occur on the surface (the formation of cracks or the onset of corrosion) [22]. The surface roughness value is usually calculated by considering the arithmetic mean of absolute values (Ra). According to Figure 2, the Ra value can be expressed by the Equation 1 [23]:

$$Ra = \frac{1}{L}\int_{0}^{l} |Y(x)|dx \qquad (1)$$

3. Results and Discussion

The surface roughness values obtained after the Al 7075-T6 aluminum alloy is ball-burnished in different parameters (Force and Al additive ratio) are given in Table 2. When the quality of the surface where the ball burnishing process is not applied and the quality of the applied surfaces are compared, it is seen that the ball burnishing process improves the surface quality.

The graph of the surface roughness changes according to different % nano-Al powder additive ratios and force parameters is shown in Figure 4. When the graphic is interpreted; although it is observed that the surface roughness value decreases as the percentage of Al additive added to the grease and the force values increase, it is observed that the effect of the % nano-Al powder additive ratio on the surface roughness is more than the force values. Because of the 50 N force value and the 10% nano-Al powder additive rate, the surface roughness value is the lowest.

Figure 1. Experimental setup

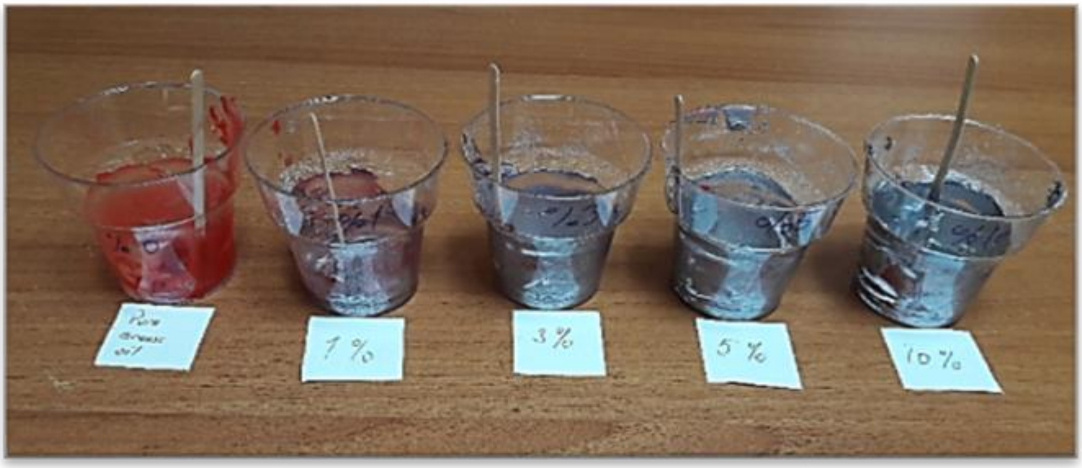

Figure 2. Grease environments with different ratios of nano-Al additive.

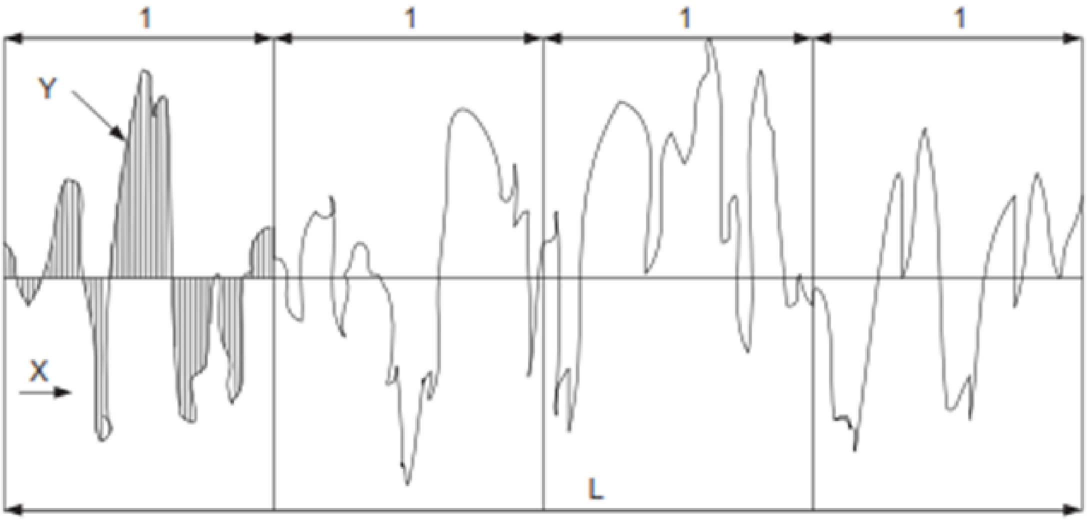

Figure 3. Profile of surface texture [23]

Table 2. Experimental parameters and surface roughness results

Experiment number	Force (N)	Environments (%nano-Al powder additive ratio)	Surface Roughness results (μm)	
			Ra	Rz
1	50	Pure	1,372	5,300
2	50	% 1	1,309	4,949
3	50	% 3	0,907	5,137
4	50	% 5	0,886	4,369
5	50	% 10	0,279	1,591
6	100	Pure	1,239	4,756
7	100	% 1	0,895	4,243
8	100	% 3	0,954	5,434
9	100	% 5	0,816	3,887
10	100	% 10	0,356	1,788
11	150	Pure	0,621	2,706
12	150	% 1	0,727	3,271
13	150	% 3	0,890	5,080
14	150	% 5	0,785	3,146
15	150	% 10	0,396	2,129
16	200	Pure	0,609	3,026
17	200	% 1	0,565	2,998
18	200	% 3	0,698	3,721
19	200	% 5	0,760	3,612
20	200	% 10	0,332	1,921

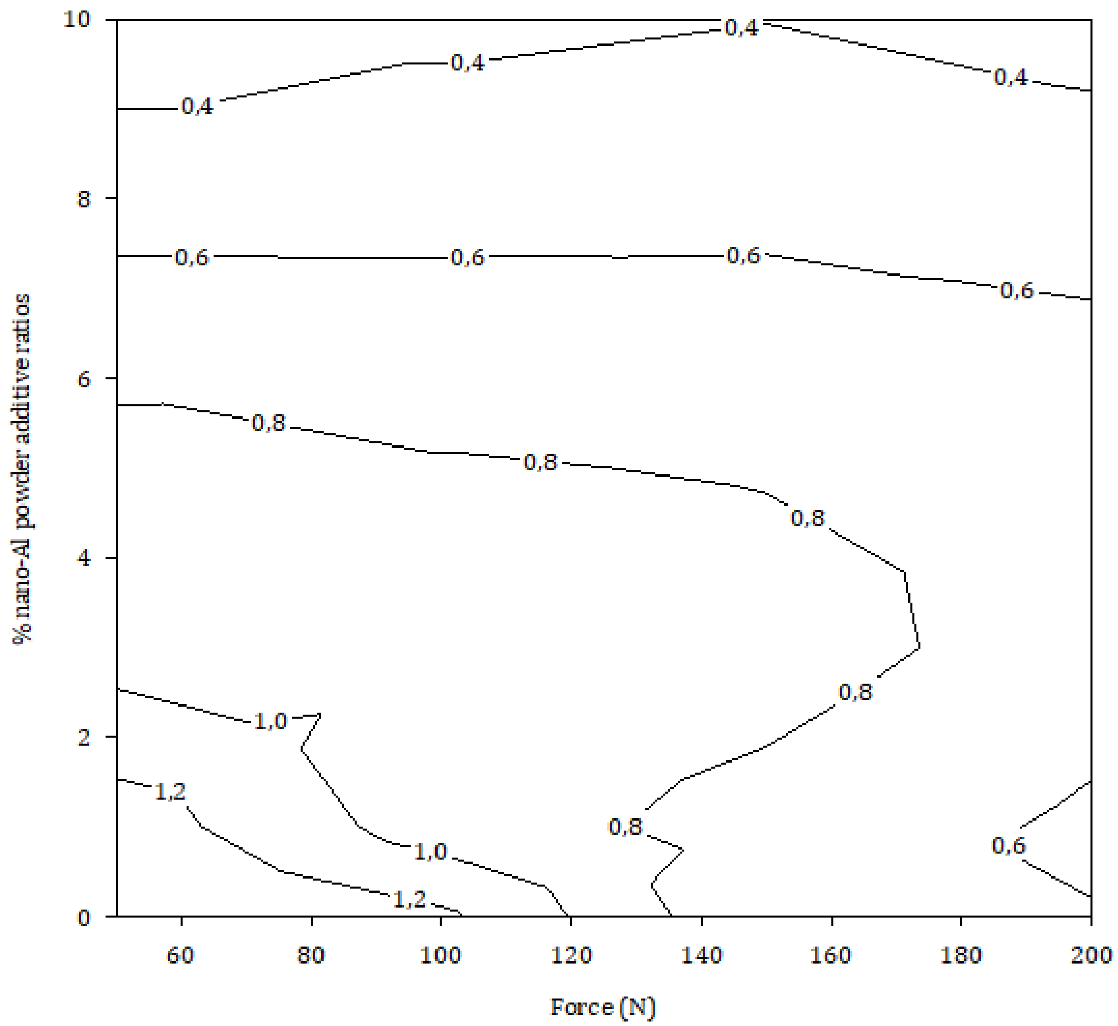

Figure 4. Variation of surface roughness according to different % nano-Al powder additive ratios and force parameters.

4. Conclusion

In this article, a study was conducted on the improvement of the Al 7075-T6 workpiece surface by mechanical methods. The experiments were carried out using the ball burnishing process, one of the mechanical surface improvement processes. In this study, when the effect of different parameters (force and % nano-Al powder additive ratio) on surface quality is examined, the following results are obtained:

• It has been observed that the best results among the measured surface roughness values were obtained in the environment of 50N and 10% nano-Al powder added grease.
• It is concluded that the increase in the contribution ratio and the force separately increases the surface quality.
• The surface roughness value of the Al 7075-T6 workpiece, which is not ball burnished, was 1.558 μm, and the surface roughness value was reduced to 0.279 μm after the ball burnishing process.

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Author contributions

Suleyman Cinar Cagan: Conceptualization, Methodology, Software, Visualization, Investigation **Berat Baris Buldum:** Data curation, Writing-Original draft preparation, Software, Validation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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