Effect of Number of Passes on Surface Properties of Burnished Aluminium Alloy

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Abstract: Basically, roller burnishing process is one of the surface finishing processes. In this process, a hard and highly polished roller will be pressed against a rotating specimen, this causes plastic flow on specimen surface from the peaks of surface irregularities into the valleys, which result in a reduction in the surface roughness considerably. This is a type of cold working which also results in improvement of micro-hardness, refinement of microstructure on the surface of the specimen under consideration. This work aims to understand the versatility of roller burnishing processes and to understand the effect of the number of burnishing passes to enhance surface properties. Surfacrroughness, electrical conductivity and microhardness were studied in current work. Experimental work was done on aluminium AA7075-T6 alloy. The parameters under which the burnishing work was done were burnishing force, spindle feed and speed and are kept constant in the present work.

Keywords: Roller burnishing, microhardness, surface roughness, AA7075-T6.

1. Introduction

Finishing processes are becoming predominant in the production of machines and instrument components, the burnishing process has fascinated great interest among the engineers and researchers due to the versatility involved in the process. To increase productivity, and to reduce machining times and to sustain competitiveness in the market of machining production systems, it is becoming crucial to improve existing technologies. Burnishing process is one surface finishing technique applied widely to improve surface properties. Many researchers are working in this area and developed analytical models, for studying surface properties. Lars Hiegemann et al. [1] conducted various experiments on ball burnishing and developed an analytical model which was used to predict the roughness after ball burnishing for a thermally sprayed coating. Kable et al., [2] examined surface roughness, microhardness on medium carbon steel by changing different parameters like speed, feed and number of passes on the drilled hole, by using Taguchi analysis, a significant improvement in hardness was observed i.e., from 377HV to 528HV and surface roughness was reduced from 2.44 µm to 0.13 µm. Recently, a newly designed ball burnishing tool made of HSS ball of 8mm diameter have been employed on AA6061 using a conventional lathe and process parameters have been optimized using Taguchi method [3]. Many researchers have worked on roller burnishing using lathe on various ferrous and non-ferrous materials [4-9]. In reference [10] roller burnishing is carried on Al₂O₃/A356 composite specimens with varying process parameters, it is clearly evident from this reference that multi passing improves surface roughness and also by this process microhardness and subsurface hardness improves. Even in mild steel roller burnishing increases hardness, Malleswara Rao et al. [11] has investigated surface hardness by varying process parameters. After the third pass hardness slightly decreased. Surface finish has a positive and longevity effect on the functioning of the machined parts. When compared to permanent metallic alloys, the biodegradable magnesium-calcium (MgCa) alloy proved to be an attractive orthopaedic biomaterial [12]. A correlation was developed between mechanical, structural properties and corrosion resistance of 18-9 stainless steel after burnishing [13]. To improve the
ductility of materials burnishing force and number of burnishing tool passes were observed to be the important parameters [14]. Many researchers have worked on roller burnishing on different types of materials in different conditions. But few researchers have worked on the effect of the number of passes on surface properties of aluminium alloys. Keeping this in view the present work concentrated on the study of the effect of the increase in passes in the modification of surface properties of AA7075 alloy.

2. Materials and Methods
In the present investigation burnishing operation was performed on AA7075-T6 rod of length 610mm and diameter 25mm (Fig. 1). This AA7075-T6 is an aerospace-grade alloy which possesses excellent strength and it is comparable with various steels, additionally, it is good at fatigue strength, but the machinability of this alloy is average. This alloy is poor at corrosion resistance because of anodic dissolution of η precipitates. Its relatively high cost limits its usage to aerospace applications. Table 1 gives the chemical composition of the base alloy AA7075-T6 is typically used in Aircraft fittings.

Table 1. Chemical composition of AA7075-T6

| Element | Si  | Fe  | Cu  | Mn  | Mg  | Cr  | Zn  | Ti  | Al  |
|---------|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Wt.%    | 0.45| 0.5 | 1.2-2 | 0.3 | 2.1-2.9 | 0.18-0.28 | 5.1-6.1 | 0.2 | 87.1-91.4 |

Fig. 1 Burnishing process setup.

The burnished and unburnished samples were tested for surface roughness on Mitutoyo surface roughness testing equipment. The hardness of the surface of both burnished and unburnished samples was measured by micro Vickers Hardness equipment as per (ASTM E 384). The microstructure of the burnished and un-burnished surfaces was observed for any refinement in the grain structure, using an optical microscope (LEICACTR6000). The electrical conductivity of burnished and unburnished specimens was measured using the Kelvin Double Bridge.

3. Results and Discussions
In the present work, base metal (AA7075-T6 alloy) properties were tested and readings were taken before and after burnishing and later various tests were conducted on the burnished surfaces. From the optical microstructure of base metal (Fig. 2) MgZn2 particles were observed throughout the α matrix [15]. After burnishing it is clearly evident from the optical micrographs (Fig. 3 (a) – 3 (f)) that the size of the
MgZn₂ particles has considerably reduced and these were uniformly dispersed in α matrix. This is attributed to the fact that the force applied during the burnishing process is sufficient to break the MgZn₂ particles and can also help in uniform dispersion of the same.

Fig. 2 Optical microstructure of base metal AA7075-T6 showing MgZn₂ Particles.
Fig. 3 Optical microstructures of AA7075-T6 alloys specimen after burnishing
(a) 1st pass (b) 2nd pass (c) 3rd pass (d) 4th pass (e) 5th pass (f) 6th pass.

3.1 Surface roughness
The surface roughness of the specimens was examined before and after the burnishing process using Mitutoyo surf test (SJ-210) and surface roughness were measured five times and an average was taken and presented in Table 2 and the same values are shown in a graph in (Fig. 4).

Table 2: Surface roughness values of AA7075T6 prior and after burnishing with different passes at Load = 12Kgf speed = 220 rpm, feed = 0.14mm/rev

| Number of passes | Surface roughness, Ra (µm) |
|------------------|---------------------------|
| Unburnished(Bases metal) | 0.30                     |
| 1                | 0.47                      |
| 2                | 0.27                      |
| 3                | 0.3                       |
| 4                | 0.22                      |
| 5                | 0.2                       |
| 6                | 0.31                      |

Fig.4 Graph showing surface roughness values of AA7075T6 before and after burnishing after different passes.
It is observed that the specimen is showing minimum roughness value after 5th pass of burnishing when compared with the unburnished specimen. Additionally, it is also observed that at initial passes the surface roughness is low compared to that after final passes. This trend can be attributed to the fact that as the number of passes is increasing the surface on the metal is becoming flaky, similar behaviour has been observed by D. G. Mahto et. Al., [16] and Gharbi, F. et. Al [17]. Hence, surface roughness is higher at the final pass.

3.2 Electrical Conductivity

The electrical conductivity on the surface of the specimens prior and after the burnishing process was measured and these values are presented in Table 3, and Fig.5 shows the graph of electrical conductivity values of the AA7075-T6 specimens before and after burnishing.

Table 3: Electrical conductivity of AA7075T6 Prior and after burnishing for various number of passes

| Number of passes | Electrical Conductivity(S/m) |
|------------------|-----------------------------|
| Unburnished (Bases metal) | 531.09 |
| 1                | 614.78 |
| 2                | 461.09 |
| 3                | 474.37 |
| 4                | 395.31 |
| 5                | 367.92 |
| 6                | 434.82 |

Fig.5 Graph of electrical conductivity values of AA7075-T6 Prior and after burnishing after different passes.

From Table 3, it is clearly understood that the electrical conductivity is decreasing, even though it has increased in the first pass. This behaviour is due to sensitivity towards stress. It is widely known that when aluminium alloys are subjected to cold work, electrical conductivity decreases, this can be attributed to an increase in dislocation population [18]. But in the final pass slightly electrical conductivity has been increased this can be attributed to the transformation of precipitates [19]. Other factors which affect electrical conductivity include precipitate size and distribution, electron scattering, lattice faults etc.,[20].

3.3 Microhardness

The microhardness test was conducted on the specimen as per (ASTM E 384) standards, for unburnished and burnished specimens 300 gf load is applied with dwell 15 seconds. Five readings were taken and average hardness values were shown in Table 4.
Table 4 Microhardness values before and after burnishing at various number of passes

| Number of passes | Microhardness, VHN |
|------------------|--------------------|
| Unburnished (Bases metal) | 258                |
| 1                | 264                |
| 2                | 272                |
| 3                | 298                |
| 4                | 323                |
| 5                | 334                |
| 6                | 345                |

Hardness has been significantly enhanced with increase in passes. Previous studies also show that the increase in the number of passes enhances surface hardness [21-22]. Hardness enhancement can be attributed to the work-hardening of the surface layer [23].

Fig. 6 Graph showing microhardness values of AA7075T6 before and after burnishing at different passes.

4. Conclusions:

In this present investigation, burnishing operation was done on AA7075-T6 with different passes and various tests were performed from which the following conclusions can be made.

1. The optical microstructure reveals MgZn$_2$ particles and their distribution. Clusters of these particles were observed in base metal and the same particles were disintegrated after burnishing process and uniformly distributed in the matrix.
2. The surface finish is improved after the burnishing process. The best surface finish was obtained at 5th pass of burnishing. After 5th pass surface roughness slightly increased due to surface flakiness on metal.
3. Electrical conductivity is decreasing, eventhough it has increased in the first pass. This behaviour is due to sensitivity towards stress.
4. Considerable improvement in hardness was noticed by increasing in the number of passes this is due to work hardening behaviour.
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