

Impact of Ball burnishing process parameters on surface Integrity of an Aluminium 2024 Alloy

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Abstract. Burnishing is cold working process which leads to a surface level plastic deformation and helps to enhance important properties like surface roughness and hardness by inducing compressive residual stresses in the material up to some certain depth. The movement of the tool along the surface of the test specimen presses down the surface peaks resulting in a very smooth surface finish. The use of ball as a deforming element gives high specific pressure leading to a better surface finish when compared with other forms of burnishing. In the present work, process of burnishing is carried out on an Aluminium 2024 alloy. The aluminium 2024 alloy is divided into 6 different regions. These regions are then subjected to burnishing by varying process parameters like feed rate and number of passes. Later surface roughness and hardness tests were performed to assess its impact on the specimen before and after the burnishing process. The outcomes show significant improvement in hardness values and reduction in surface roughness.

1. Introduction

The components used for aerospace applications fail mainly due to cyclic loads as they are constantly subjected to high cyclic and low cyclic loads. A poor surface finish would increase the rate of crack propagation and gradually leads to the failure of component. There are various surface treatment processes available to enhance surface properties like shot peening, laser shock peening, deep cold rolling, Burnishing and so on, which helps to improve the fatigue life of a component. In this work ball burnishing surface treatment is employed to improve the surface properties. Being a chipless process, it is essentially a forming operation that occurs on a small scale in which strain hardening is induced to enhance the surface strength and hardness with mirror like surface finish and induces high compressive residual stresses which helps to improve the fatigue life. The process parameters like burnishing pressure, force, speed, feed, types of lubricant will Ball burnishing mainly focuses on process parameters like pressure (force), speed, and feed, followed by number of passes, ball diameter, lubricant, etc., on surface integrity. In hydrostatic ball burnishing, due to pressurized fluid flowing over the tip of tool and work piece surface helps in ways like lubricating and cooling.



2. Selection of Test Specimen

Aluminium alloy 2024 is an Aluminium alloy with copper as the primary alloying element. It is used in applications requiring high strength to weight ratio, as well as good fatigue resistance. It is weldable only through friction welding and has average machinability. It has an ultimate tensile strength of 469 Mpa and a yield strength of 441 Mpa. The table below shows the chemical composition of an Aluminium 2024 alloy. Thus the specimen material should be selected such that an improvement can be brought in its properties and it helps to improve the efficiency of the system in which it is working.

Table 1 Composition of Aluminium 2024 alloy

| Composition | Al | Cu | Cr | Mg | Mn | Si | Zn | Fe | Ti |
|-------------|------|-----|-----|-----|-----|-----|------|-----|------|
| Percentage | 94.7 | 4.9 | 0.1 | 1.8 | 0.9 | 0.5 | 0.25 | 0.5 | 0.15 |

3. Experimentation

The ball burnishing tool has been developed to control the force on the work piece. This can be done by a spring and screw mechanism provided. By tightening the screw, the force on the specimen can be increased. By using the formula $F=kx$, we can calculate the burnishing force where 'F' stands for burnishing force (in Newton), 'k' stands for spring constant (in N/mm) and 'x' stands for the spring deflection (in mm). The hydraulic oil supplied to the tool holds the ball in its position during burnishing by applying pressure and also acts as a lubricant. The oil can be collected and re-used after Burnishing process.



Figure 1. Burnishing process carried out on the specimen

Here, the work piece is clamped to the lathe chuck and the tool is placed in the tool post. The tool is held tight in its position by the tool post. The hydraulic circuit is completed by connecting the pipes and opening all the valves. The hydraulic circuit also consists of needle valve and feed check valves which helps to protect the tool from any sudden increase in the hydraulic oil pressure. The hydraulic circuit is then switched on and the tool is brought in contact with the Aluminum specimen. The speed of the lathe is adjusted accordingly. The burnishing process is carried out on the parts wherever

required, i.e., by varying the force and the number of passes. The corresponding readings are noted and tabulated. The specimen is then cleaned for further tests.

The following table shows the various parameters which were selected during the process of burnishing. A higher speed was selected as it results in a better surface finish. The pressure and feed values are selected within the operating range in order to ensure that there is no buckling of the test specimen.

Table 2 Burnishing process parameters

| BURNISHED REGIONS | SPEED (RPM) | FEED (mm/rev) | NUMBER OF PASSES |
|-------------------|-------------|---------------|------------------|
| 1 | 1200 | 2 | 1 |
| 2 | 1200 | 1 | 1 |
| 3 | 1200 | 0.5 | 1 |
| 4 | 1200 | 3 | 3 |
| 5 | 1200 | 3 | 6 |
| 6 | 1200 | 3 | 9 |

4. Specimen Testing

4.1 Surface roughness Test

Once the burnishing process is completed the test specimen is now tested for various parameters. First the surface roughness test was performed on the specimen. The testing was carried out at Geological and Metallurgical Testing laboratories, Bangalore. The Surface roughness test was performed using a Surface Roughness Measuring Tester SJ-210 manufactured by Mitutoyo.

Table 3 Surface roughness values

| Location | Measured Values (r_a) in μ | |
|----------|------------------------------------|---------|
| | Individual Values | Average |
| 1 | 2.270,2.234,2.790,2.334,2.272 | 2.380 |
| 2 | 1.121,1.152,1.586,1.520,1.880 | 1.452 |
| 3 | 1.379,1.352,1.468,1.587,1.799 | 1.517 |
| 4 | 1.661,1.808,1.662,1.321,1.818 | 1.654 |
| 5 | 1.936,2.226,1.982,2.778,2.284 | 2.241 |
| 6 | 1.914,2.182,2.375,2.027,2.388 | 2.177 |
| 7 | 2.253,1.982,2.325,2.022,1.910 | 2.098 |

4.2 Hardness Test

surface hardness Test was conducted using a Rockwell hardness testing machine. The measurements were taken on scale B as Aluminium is a soft metal. The indentations were made on many points on the specimen and the average of these values were taken to get the final reading.

Table 4 Surface roughness values

| Location | 1 | 2 | 3 | 4 | | 6 | 7 |
|--------------|----|----|----|----|----|----|----|
| Hardness HRB | 80 | 70 | 73 | 78 | 78 | 80 | 77 |

5.Results and Discussion

The above graph shows us the variation of Surface roughness with feed. As we can see, the surface roughness increases as the feed increases. At low feed rates, all the irregularities on the surface are reduced to lower height. However at extremely low feed rate levels, the possibility of the ball passing over the same spot is considerably greater. The longer period of contact causes excessive strain hardening and causes flaking of the surface layer with a very poor surface finish. At higher feed rates, the distance between two successive ball traces increases and thus has a lesser chance to flatten the peaks. This also results in a poor surface finish. Thus an optimum value of feed rate should be selected.

The surface roughness reduces only up to a certain number of passes. 3-4 passes is more than sufficient for soft materials like Aluminium. Increasing the number of passes ensures that all the peaks are compresses leading to an improvement in the surface finish. However when the number of passes are increased beyond a certain limit, there is a deterioration in surface finish due to over hardening . The plastic deformation produced by the application of pressure on the material surface creates a localized cold worked zone. This results in the improvement of hardness. The hardness increases as the number of passes increase because of the increase in plastic deformation. Beyond a certain extent it ceases to increase because of excess of work hardening effect. The variation of hardness with feed rate is also similar. Hardness reduces with increase in feed rate because the distance between the successive traces will be very large. The above graph represents the variation of hardness with feed rate. The hardness value increases at lower feed rate because of the work hardening effect. However at higher feed the excessive work hardening effect reduces the hardness value. Also the value of speed during burnishing should be selected carefully as high values of speeds results in a bad surface finish due to the vibration produced at such speeds.

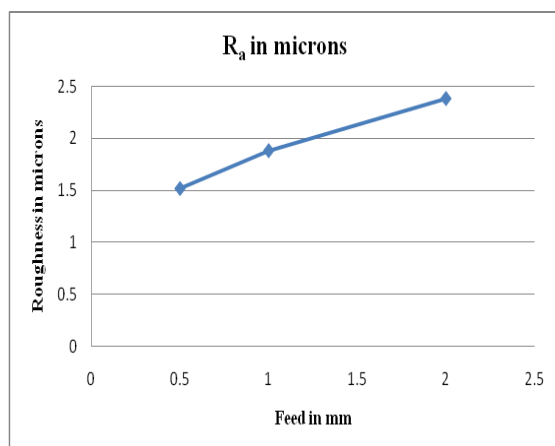


Figure 2. Variation of roughness with feed

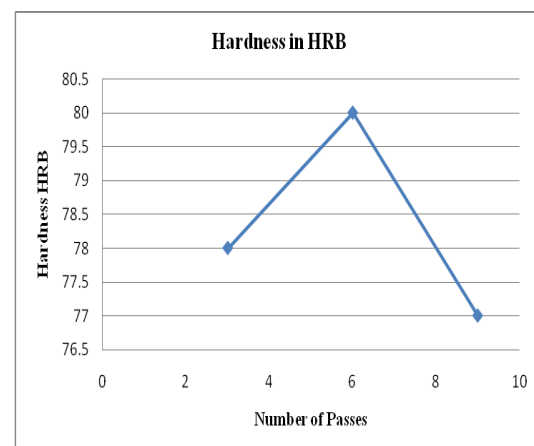


Figure 3. Roughness with number passes

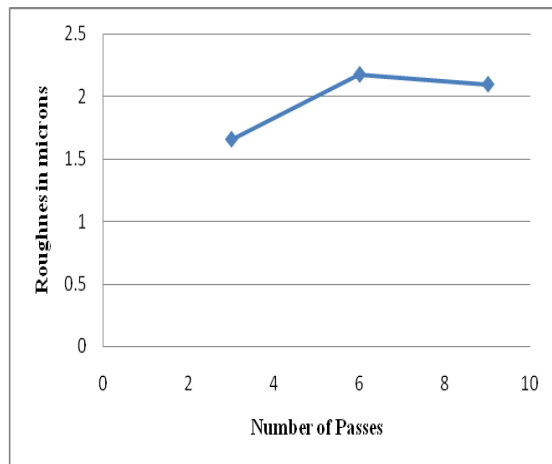


Figure 4. Variation of Hardness with number of passes .

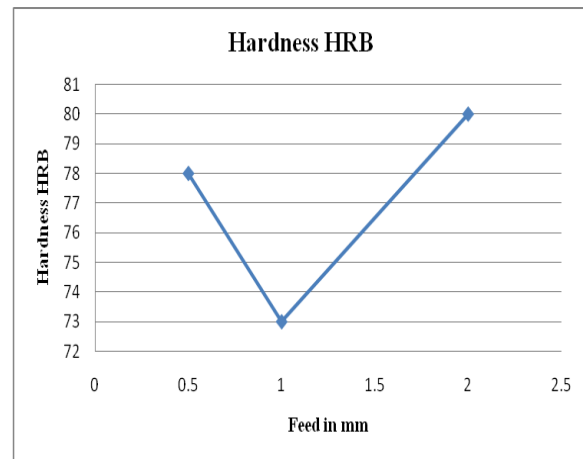


Figure 5. Variation of hardness with feed rate.

6. Conclusions

A ball burnishing tool is developed and fabricated according to the required specifications. The burnishing process is performed on the Aluminium 2024 specimen by varying various surface parameters like speed, feed and number of passes. The results of surface roughness and hardness are then compared before and after the burnishing process. Following are the conclusions drawn from the above project.

- There is an improvement in the hardness after the burnishing process due to the effect of strain hardening.
- There is an improvement in the surface finish after the burnishing process, which is clearly indicated by the low values of surface roughness. The surface roughness increases with extremely low and high feed rates.
- The process parameters like feed rate, number of passes and the speed must be selected carefully in order to get significant improvements in the surface integrity.

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