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Improving By Ball Burnishing For Internal Turned Surfaces

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Abstract: *The paper presented is a work started in summer 2014 for improving surfaces of turned holes. The work was confined to two materials; aluminum alloy and brass alloy. The internal machined surfaces were burnished by ball burnishing tools. Experimental work was carried out on a lathe machine to establish the effect of the internal ball burnishing parameters; namely, burnishing feed rate, speed, force and number of tool passes on the Surface roughness and surface hardness. The operation was carried out at load pushing speed 24 m/min through the hole. Turned Al-Br specimens were divided into groups, the parameters were changed with each group. The optimum values of surface roughness and surface hardness were obtained where the surface roughness improved from 3.14 µm to 0.14 µm for Al µm and from 2.25 to 0.16 for brass and the surface hardness improved from116 HV to 184 HV for Al and from 182 to 244 HV for brass.*

Keywords: Ball Burnishing - Surface roughness - surface hardness.

1. Introduction

Burnishing is a cold rolling process without removal of metal. A set of balls rolls on the surface of component as a result of which all the pre-machined peaks get result into valleys thus giving mirror like surface. The burnishing is chip less machining which can be used to improve the surface roughness and surface hardness on any metal work piece.

Machined surfaces by conventional manufacturing processes such as turning and milling have inherent irregularities and defects like tool marks and scratches that cause energy dissipation (friction) and surface damage (wear) [1].

Work on the burnishing process has been investigated by various researches on lathes and milling machines for a wide range of materials; Ugur Esme [2], worked on use of grey based Taguchi method in ball Burnishing process for the optimization of Surface roughness and micro hardness of AA 7075 aluminum alloy. Based on their work it was predicted that the burnishing force has maximum contribution of affecting the surface roughness. The contribution of burnishing force and no. of tool passes was more which 71.59% for force and 15.75% for no. of passes.

F. Gharbi, S. et al. [3], focused on the effect of the burnishing force on the surface quality and on the service properties of AISI 1010 steel hot-rolled plates. The optimal burnishing parameters had been determined to be 300 N, 235 rpm, and 0.18 mm/rev. At the optimal condition of burnishing force, the ductility of AISI 1010 steel was improved by 49%.

Prafulla Chaudhari and Anand Nilewar [1], used double ball burnishing process with turning without releasing the work-piece. The surface roughness improved from about Ra=2.5 to about 0.2 µm, and roundness error from about 7.3 to about 2 µm. The best results of surface roughness and roundness error were obtained with burnishing force of 150N. The smaller roundness error also can be achieved by using burnishing speeds between 60.3, and 85.7 m/min. with a burnishing feed of 0.11 mm/rev.

A. A. Ibrahim et al. [5], investigated the influence of burnishing parameters on AISI 1018 Low Carbon Steel specimens by applying a new burnishing technique which enables both single and double ball burnishing process in site after turning without releasing the specimen. The surface roughness of the turned test specimens were improved by burnishing from about Ra = 2.4 to about 0.09 µm. Optimum conditions of a Surface finish was obtained with double ball burnishing process at burnishing force of 210N, speed of 85.7 m/min, burnishing feed of 0.11 mm/rev, and number of tool pass was three.

The analysis on ball burnished plane surface, mild carbon steel M1044 was undertaken by Dr Majeed Némat et al. [6], the plane burnished surface finish and hardness improvements of around 89 % and 70 %respectively were obtainable. Around 35 µm physical depth of the hardened surface layer was the result at the obtained optimum burnishing force and feed values of about 7.8Kgf and 107 mm/min respectively.

A. S. Maheshwari and Dr. R. R. Gawande [7], have investigated the effect of stiff ball burnishing parameters on surface hardness of Titanium alloy. A quadratic regression model was developed using RSM with central composite design (CCD). Maximum surface hardness was achieved at speed 900 rpm, feed 300 mm/min, and depth of penetration 0.5µm and number of passes 3. The percentage increase in surface hardness was about 8 to 12% and number of passes was the most significant factor determined.

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Berat Baris [8], applied ball burnishing process to AZ31B magnesium alloy with different parameters like force, number of passes, feed rate and speed. For reducing number of experiments, Taguchi method was used and optimum burnishing condition was determined according to S/N ratios. optimum results for surface roughness was defined as the burnishing force of 250 N, the burnishing feed rate of 0,1 mm/min, the burnishing speed of 200 rpm and burnishing passes of 2. For surface hardness, the burnishing force of 250 N, burnishing feed rate of 0.1 mm/min, burnishing speed of 600 rpm and burnishing passes of 1 was obtained best results.

2. EXPERIMENTAL DETAILS

2.1 Test equipment

The experimental work was conducted on a simple lathe machine (ZMM Sliven-universal lathe type cy630).
The burnishing setup was used where an apparatus compression testing that shown in fig. (1) fixed to the three jaw lathe chuck which clamped the work piece. The lathe guide was used to push the burnishing ball axially through the hole with the aid of an oil of type CO-OP Hydraulic 4 ISO VG 68 and El Ahleya grease. The operation was carried out at load pushing speed of 24/min through the hole. The axial force was about 10 kgf, measured by the dynamometer. Turned Al-Br specimens were divided into groups. The parameters were changed with each group and their influence on surface roughness and surface hardness were studied.

2.2 Test specimens

The work-pieces were received as hollow cylindrical bars of 25mm diameter. The bars were cut to appropriate lengths (30 mm) and internally turned to a diameter of 10, 15 and 20mm as shown in fig.2.The tolerance of the set of aluminium samples was 0.1 mm and for the brass samples was 0.2 mm.

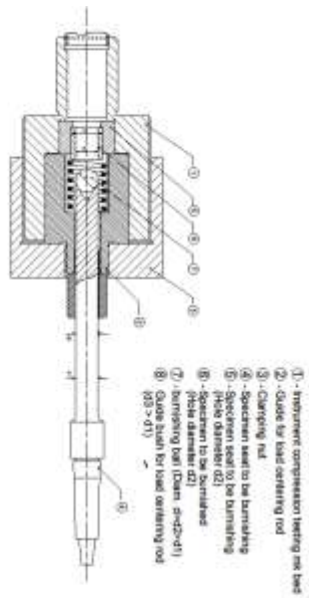

Fig.1 The apparatus.

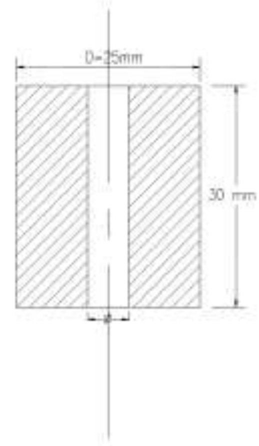

Fig.2 The work-piece.

2.3 The burnishing parameters

The parameters affecting the plastic deformation process are variable, In the present work the parameters selected are; the ball diameter, the burnishing feed, the burnishing speed, the burnishing force and the number of burnishing tool passes.

2.4 Measurement of the surface roughness values

Initial surface roughness (Ra) of Aluminium and Brass measured after turning. The initial surface roughness Ra of most work materials was found to be in a range of 2.67 to 3.65 µm for aluminium and 1.86 to 2.64µm for brass and measured again for each specimen after ball burnishing process by the device in fig.(3). The device was charged and adjusted. The work-piece was put in its place in the device. The needle moved across the wall of the work-piece to measure the surface roughness (Ra).

Fig.3. The surface roughness measurement device.

2.5 Measurement of the surface hardness values

Small pieces have been cut from each work-piece to enable the measurement then located in its place on the adjusted device (Vickers hardness tester) indicated in fig.(4). The subjected load was 980 N. The initial hardness of aluminium HV was found to be in the range of 114 to118 kgf/mm² and from180 to185 kgf/mm² for brass. The final surface hardness values (HV) are measured after ball burnishing process for each work-piece.

Fig.4. The hardness test.

3. Results and discussion

3.1 Effect of the burnishing Feed rates on surface roughness

The effects of burnishing feed on the Ra for both work-piece materials are shown in figures 5 and 6, respectively. The figures show that the surface roughness increases with the increase of the burnishing feed. Thus, to produce optimum surface roughness via burnishing, a burnishing feed of approximately 0.1 mm/ rev is considered to be the optimum value for both aluminum and brass with process conditions of speeds V=24 m/min and P=10 kgf.

3.2 Effect of the burnishing speed on the surface roughness

he relations between burnishing speed and surface roughness are shown in figures 7&8. It showed the effect of burnishing speed on surface roughness at constant feed rate of 0.1mm/rev., under a constant burnishing force p= 10kgf . The optimum surface smoothness for aluminum was at a speed of 34m/min, 0.1 mm/rev feed rate and 20 mm ball diameter, while the worst one was obtained in figure 3 with a speed of 14 mm/min and 10 mm ball diameter with the same force and feed rate. The optimum surface smoothness for brass was at a speed of 24 m/min, 0.1 mm/rev feed rate and 20 mm ball diameter, while the worst one was obtained in figure 8 with a speed of 14 mm/min and 10 mm ball diameter with the same force and feed rate. For ball burnishing better surface roughness can be achieved using low values of forces with low speeds or using high forces with high speeds.

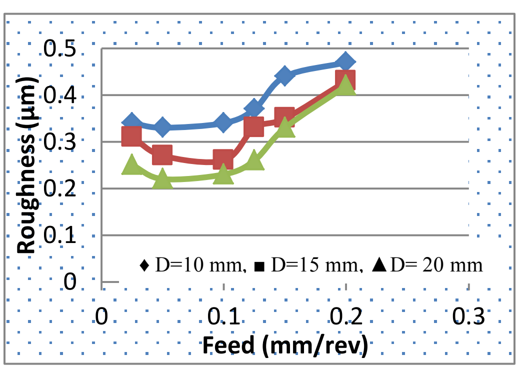

Fig.5

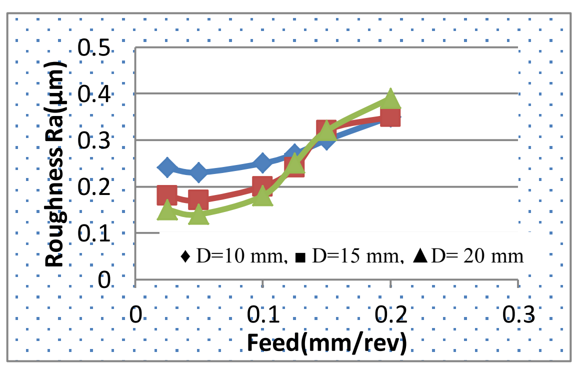

Fig.6

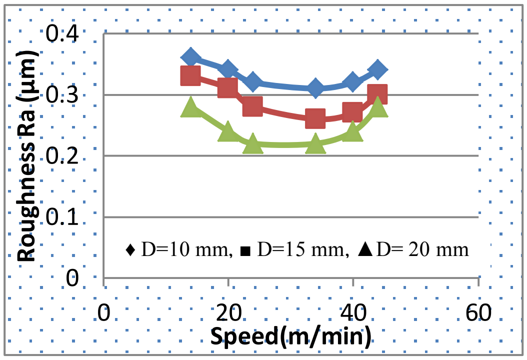

Fig.7

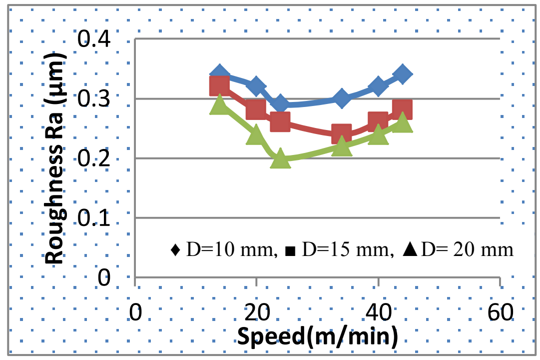

Fig.8

3.3 Effect of the burnishing force (F) on the surface roughness (Ra)

The burnishing force experiments conducted at constant speed of 24 m/min and under a feed rate of 0.1mm/rev. It can be observed from Fig.9 and 10 that the increase in burnishing force in ball burnishing process from 5 to 20kgf leads to a decrease in surface roughness for aluminum. Then further increase of the force above 20kgf leads to an increase of surface roughness at the mentioned feed. The same is with brass where the surface roughness decreased with the forces from 5 to 15kgf and increased after that value. The highest surface smoothness for aluminum was obtained at force of 20kgf at a feed rate of 0.1mm/rev and 20mm ball diameter and for brass, the optimum surface smoothness was obtained at force of 15kgf, 0.1mm/rev feed rate and 20mm ball diameter. Further increase in the feed with high force deteriorates the surface finish.

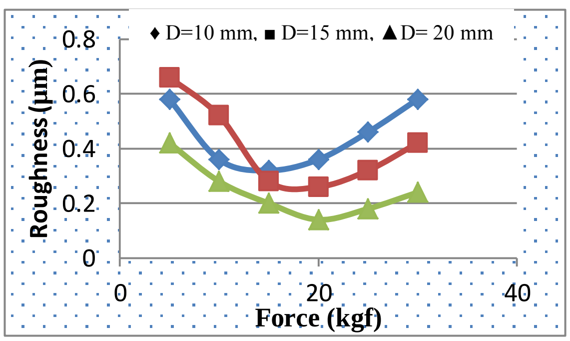

Fig.9

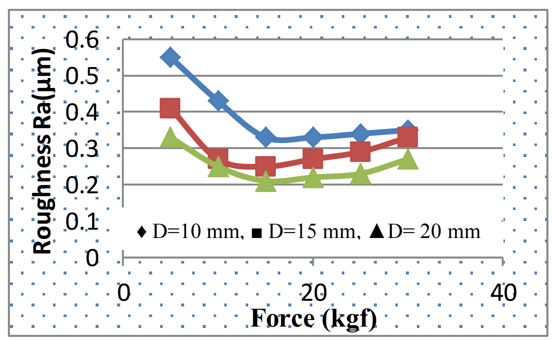

Fig.10

3.4 Effect of the number of tool passes on the surface roughness

Ball burnishing curves in figures 11 and 12 indicated that the surface roughness reached a minimum value by increasing the number of burnishing tool passes, after which it started to increase with further increase in the number of passes. As it can be seen from the figures above a reduction in surface roughness is taking place up to the third pass. Beyond the third pass the surface roughness started to increase. The investigation showed that ball burnishing improved the surface roughness with respect to no of passes and achieved the minimum value of surface roughness and the optimum result occurred with the largest ball diameter (d=20mm) for both aluminum and Brass.

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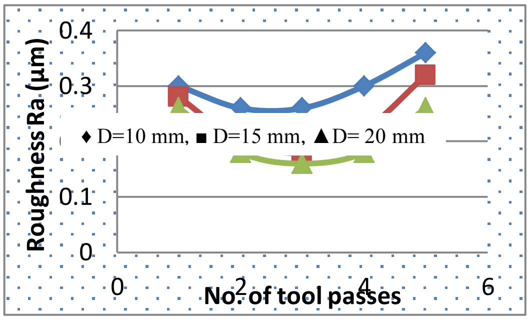


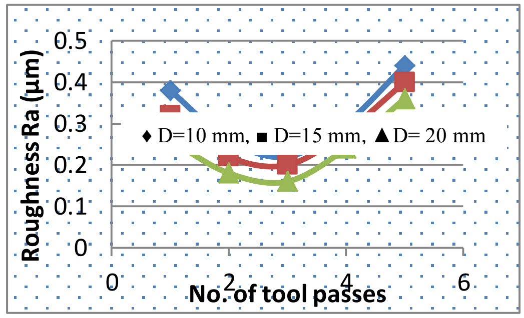
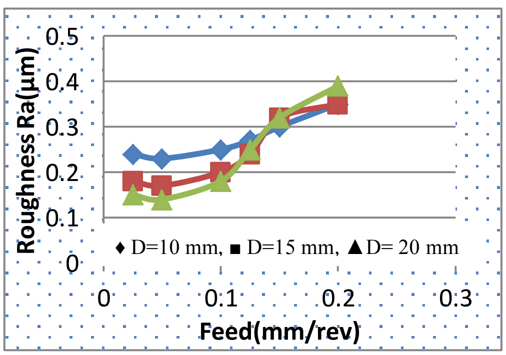


FIG.11 **FIG.12**

3.5 EFFECT OF THE FEED RATES ON THE SURFACE HARDNESS

As the burnishing feed rate increases, the surface hardness decreases for both materials aluminum and brass work-pieces as shown in figures 13 and 14 at the same process conditions of P=10kgf, V= 24m/min and d3 and number of passes =1. The optimum surface hardness was obtained at feed rate of 0.025mm/rev and 10mm ball diameter for both materials where HV for aluminum was 166 kgf/mm² and for brass was 214 kgf/mm². This is due to as the feed rate increase, the heat subjected to the surface increases.



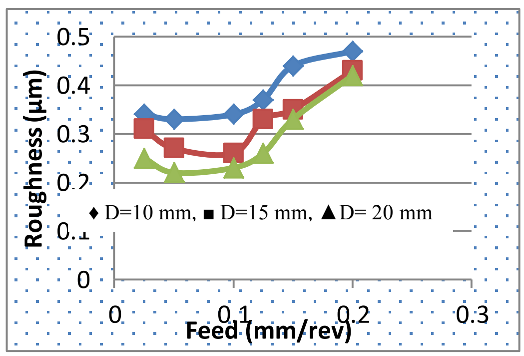


Fig.13 Fig.14

3.6 Effect of the burnishing speed on the surface hardness

In figures 15 and 16, the hardness of the work-pieces surfaces considerably decreases with the increase of the burnishing speed within the range used in this work (13 to 42 m/min). It is believed that the deforming action of the ball decreases with an increase in burnishing speed for both materials. The highest surface hardness was obtained with the a speed of 13m/min and 10mm ball diameter for aluminum where the surface hardness was 164 HV and the same for brass the maximum surface hardness was 214 HV with the same speed and ball diameter.

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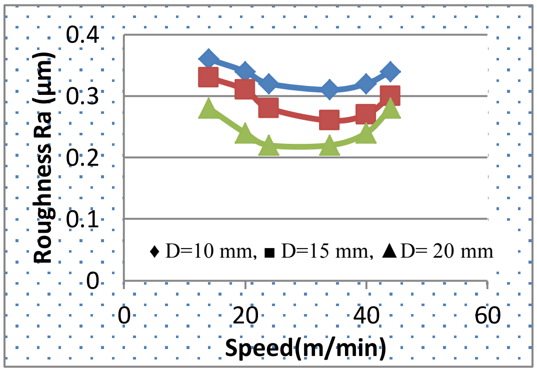

Fig.15

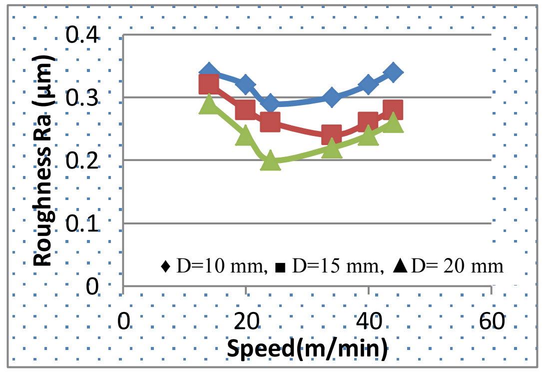

Fig.16

3.7 Effect of the burnishing force (F) on the surface hardness (HV)

The surface hardness is directly proportional to the applied force under the experimental conditions used of f= 0.1 mm/rev, V=24 m/min and number of tool passes = 1, i.e. an increase in force increases the surface hardness for both work-pieces materials. The optimum results had obtained with brass work-pieces of 10 mm diameter where HV= 244kgf/mm² as shown in figures 17 and18.

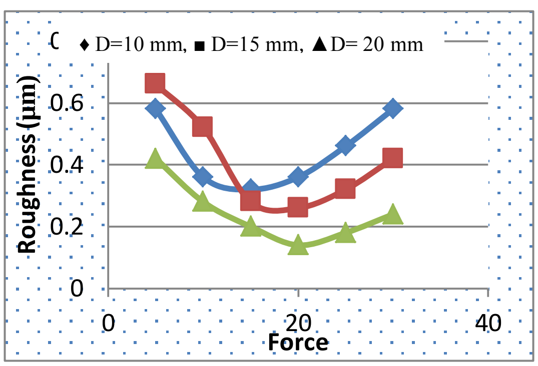

Fig.17

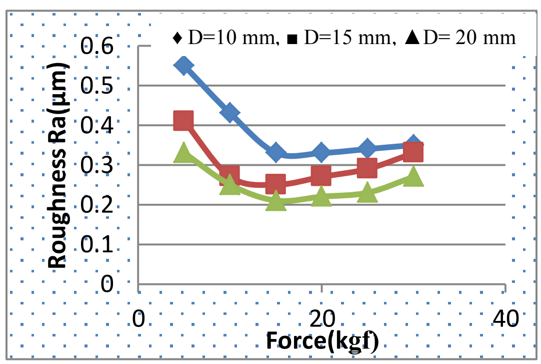

Fig.18

3.8 Effect of the number of tool passes on the surface hardness

Figure 19 and 20 shows the surface hardness (HV) owing to increases for both work-piece materials used by increasing the number of tool passes under constant conditions f= 0.1 mm/rev, V= 24 m/min and P= 10kgf. This can be attributed to the condensed grain structure and the increase in the structural homogeneity of the surface layers. Hence, the optimum hardness for both materials is considered to be 5 pass of 10mm ball diameter of brass material where HV=238kgf/mm².

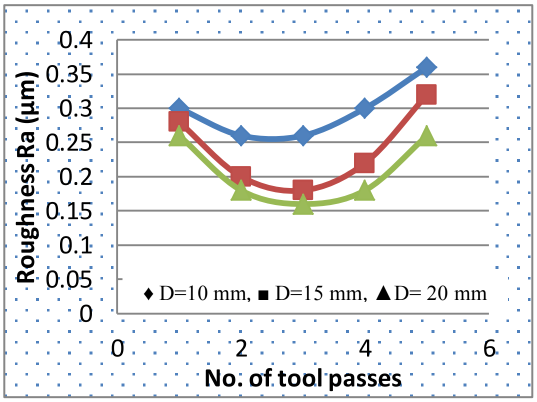

FIG.19

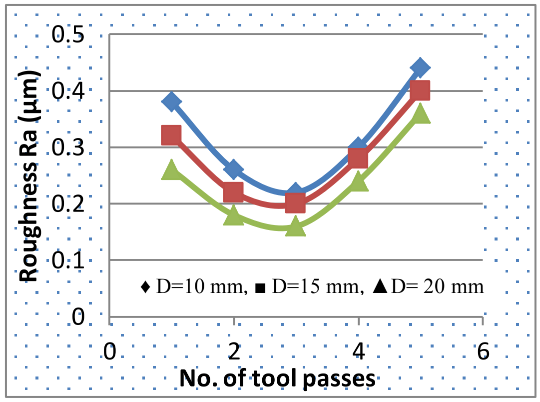

FIG.20

3.9 Comparisons between Aluminum and Brass materials

3.9.1 Effect of the burnishing feed rates on the surface roughness

Fig.21 shows the different effect of burnishing feed rates on the surface roughness for Al and Br. Al has less surface roughness values than Br over the different diameters. As the diameter increases and the feed increase, the surface roughness decreases. In general, the best surface roughness is at diameter of 20mm for both materials and higher in brass than aluminum where burnishing conditions were V =24m/min, P = 10kgf and number of passes N =1.

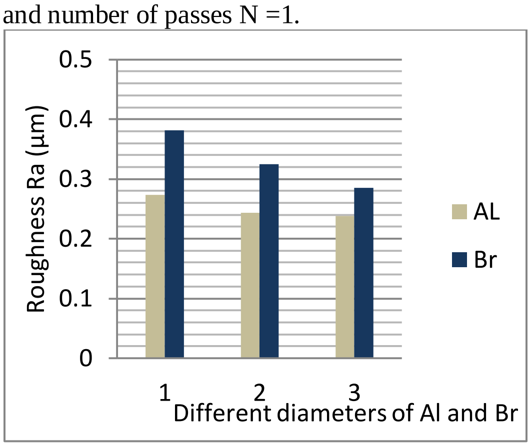

Fig. 21

3.9.2. Effect of the burnishing feed rates on the surface hardness

Fig. 22 indicates that the brass has higher hardness values than aluminum. The surface hardness decreases by the increase of the diameter and by the increase in feed. The higher hardness values for both materials are at diameter of 10 mm and it's clearly higher in brass material, but the hardness values are very close for the diameters in the same material. The burnishing conditions were V =24 m/min, P = 10 kgf and number of passes N =1.

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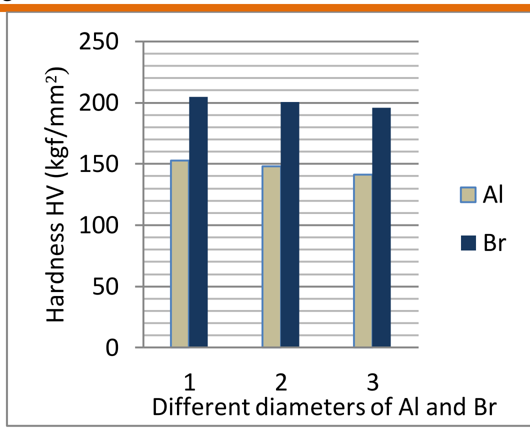

Fig. 22

3.9.3 Effect of the burnishing speed on the surface roughness

In fig. 23, as the speed and diameter increase, the surface roughness decreases. Al has more surface roughness than Br. The values are close for both materials and for each diameter. The best surface roughness is at 10 mm diameter for the two materials that tested under speeds of 14 to 44 (m/min) at the same conditions of f =0.1mm/rev, P =10kgf and number of passes N =1.

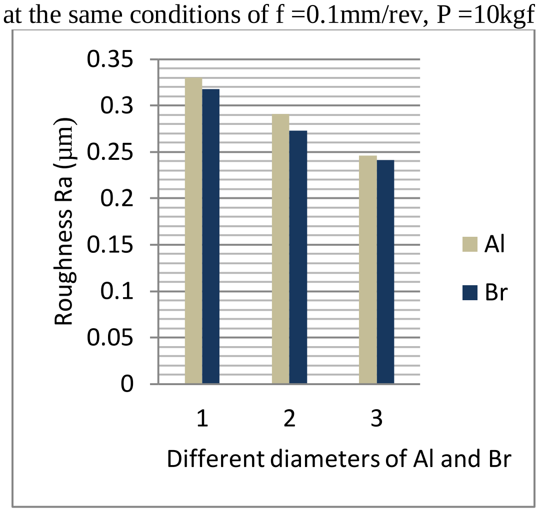

Fig. 23

3.9.4 Effect of the burnishing speed on the surface hardness

It's observed in fig. 24Al has less hardness than Br. As the diameter increase and speed increase, the surface hardness decreases. 10 mm diameter of brass has the best value of surface hardness. Burnishing conditions: f =0.1mm/rev, V =24m/min, P =10kgf and number of passes N =1.

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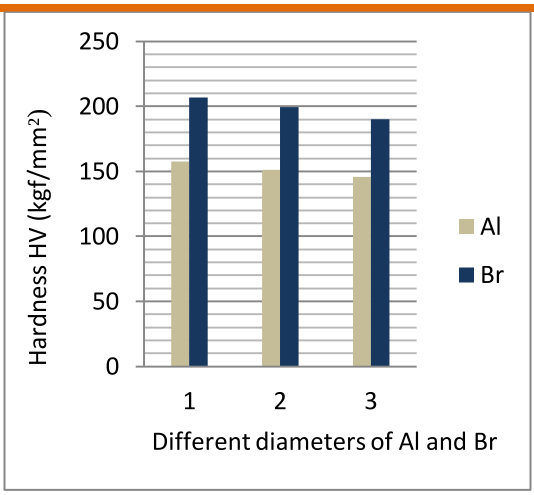

Fig. 24

3.9.5 Effect of the burnishing force on the surface roughness

As shown in fig. 25, Al has more surface roughness values than Br. The surface roughness decreases as the diameter and force increase. As seen the 10mm diameter is much rough than 20mm diameter for both materials. Burnishing conditions: f =0.1mmrev, V =24m/min and number of passes N =1.

3.9.6 Effect of the burnishing force on the surface hardness

As seen in figure 26, the Al has less surface hardness than Br. The surface hardness decreases as the diameter increases. The values are close for each material. Burnishing conditions: f =0.1mm/rev, V =24 m/min and number of passes N =1.

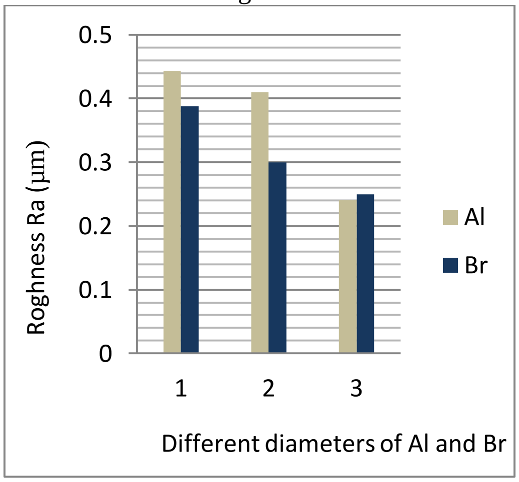

Fig. 25

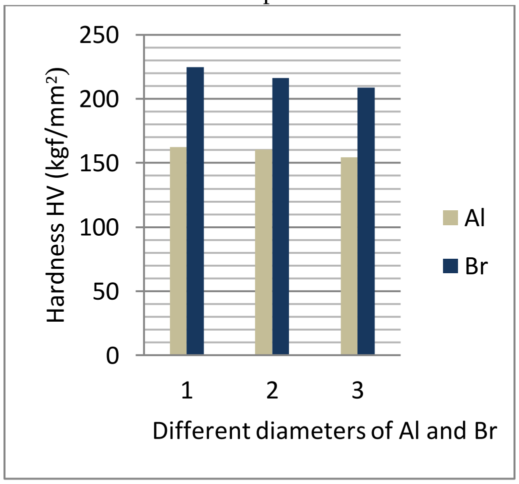

Fig. 26

3.9.7 Effect of the number of tool passes on the surface roughness

In fig.27, Al has more surface roughness than Br. The surface roughness decreases as the diameter increases in both materials. Burnishing conditions: f =0.1mm/rev, V =24 m/min and P =10kgf.

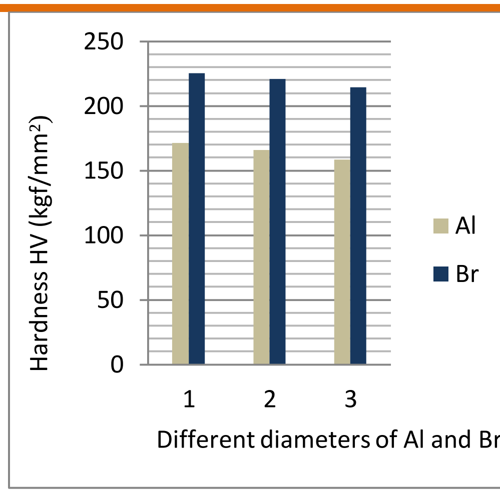

Fig. 27

3.9.8 Effect of the number of tool passes on the surface hardness

It can be seen seen in fig. 28, Al has less surface hardness than Br. As the diameter increases, the surface hardness decreases for both materials. Burnishing conditions: f=0.1mm/rev, V =24m/min and P = 10kgf.

4. Conclusion

Under the burnishing conditions considered in the experimental work described before, the following can be drawn:

1- The surface roughness decreases with the increase of the feed rate, burnishing speed, burnishing force and number of tool passes, to a certain limit then it starts to increase with each of the above mentioned parameters.
2- The surface hardness decreases with the increase of the feed rate, burnishing speed, while the surface hardness increases with the burnishing force and the number of tool passes.
3- Increasing in burnishing force causes increasing in the surface hardness.
4- Large diameter's ball seems to be more effective in improving the surface roughness, while small diameter's balls seem to be more effective in increasing the surface hardness.
5- The surface roughness had decreased from 3.14 µm to 0.14 µm for Al µm and from 2.25 to 0.16 for.
6- The experimental work shows that an increase in surface hardness of 116 HV to 184 HV for Al and from 182 to 244 HV for brass.
7- An interaction effect between the ball material and linear feed were also evident.
8- The burnishing technique followed in the study proved to be a very efficient one in improving all surface qualities of machined surfaces.

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