

Experimental investigation of the influence of burnishing tool passes on surface roughness and hardness of brass specimens

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Abstract

The process of burnishing is performed by applying a highly polished and hardened ball or roller with external force onto the surface of a cylindrical work piece. The burnishing process increases the surface hardness of the work piece, which in turn improves wear resistance, increases corrosion resistance, improves tensile strength, maintains dimensional stability and improves the fatigue strength by inducing residual compressive stresses in the surface of the work piece. In the present experimental work, both ball and roller burnishing tools are used. Experiments are conducted to study the performance of the ball and roller burnishing tools on lathe, along with the influence of number of burnishing tool passes on the surface roughness and surface hardness of brass specimens. The results revealed that improvements in the surface finish and increase in the surface hardness are obtained by the increase of the number of burnishing tool passes in both ball burnishing and roller burnishing on the brass specimens.

Keywords: Ball burnishing, Roller burnishing, Dynamometer, Brass.

Nomenclature: P_b Burnishing force normal to the specimen; P_r Burnishing force normal to the axis of the specimen in roller burnishing (kgf); N Number of burnishing tool passes; d_b Burnishing ball diameter (mm); d_r Burnishing roller diameter (mm); f_b Burnishing feed (mm rev⁻¹); V_b Burnishing speed (m min⁻¹); HRB_i Initial Rockwell hardness (B) scale of the turned specimen; R_a Arithmetic surface roughness average (μm); R_{ai} Initial arithmetical surface roughness of the turned specime

Introduction

In burnishing process, a hard and highly polished ball or roller is made to press against the surface of a metallic

Fig. 1. Burnishing process.

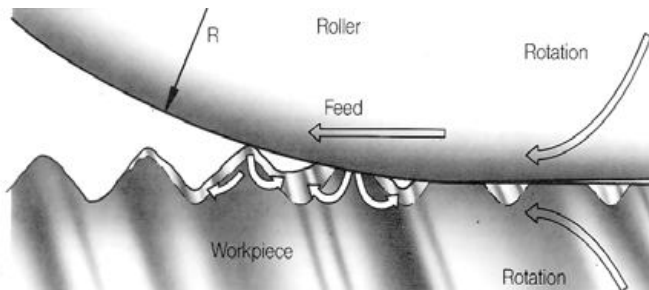
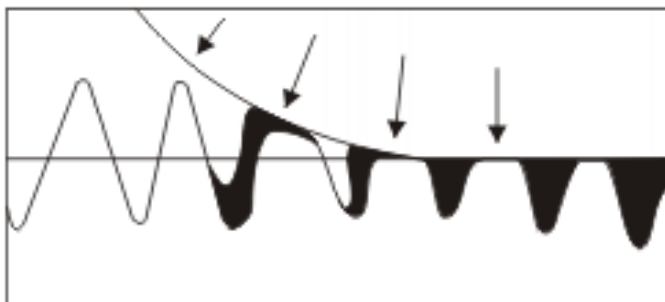


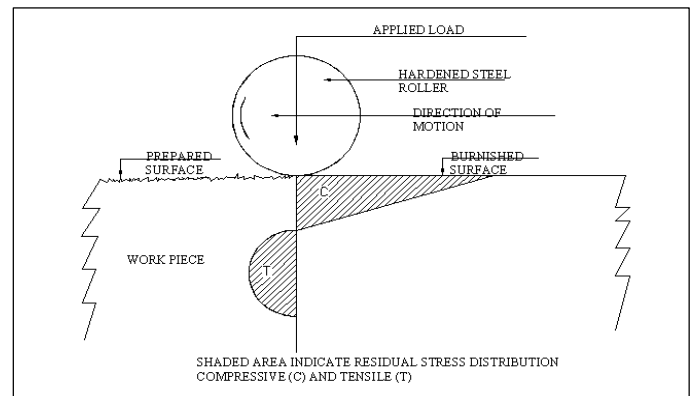
Fig. 2. Material flow from peaks to the valleys in the burnishing process.



work piece with high pressure. Due to this, the peaks of the metallic surface are plastically deformed, when the applied burnishing pressure exceeds the yield strength of the metallic material, to fill the valleys (Hassan & Al-Bsharat 1997) as shown in Fig.1 and Fig. 2. The result is that the surface of the metallic work piece will be smoothed.

The material is left with a residual stress distribution that is compressive on the surface, due to the plastic deformation, as shown in Fig. 3. As a result, the surface hardness, wear resistance, fatigue resistance, yield strength, tensile strength and corrosion resistance are

Fig. 3. Distribution of residual stresses on the work



improved because of the changes in surface characteristics due to burnishing, as mentioned by many authors (Shneider, 1967; Murthy, 1981; Siva Prasad 1988; Loh, 1991).

Burnishing is considered as a cold- working finishing process, differs from other cold- working, surface treatment processes such as shot peening, and sand blasting etc., in that it produces a good surface finish and also induces residual compressive stresses at the metallic surface layers (Wang, 1999). Also, burnishing is economically beneficial, because it is a simple and less costly process, requiring less time. Semi skilled operators are enough to obtain a high- quality surface finish (Thamizhmnai, 2008).

The influence of number of burnishing tool passes on the surface roughness and hardness of brass specimens is studied in the present experimental work, in both ball and roller burnishing processes

Tools, equipment and machines

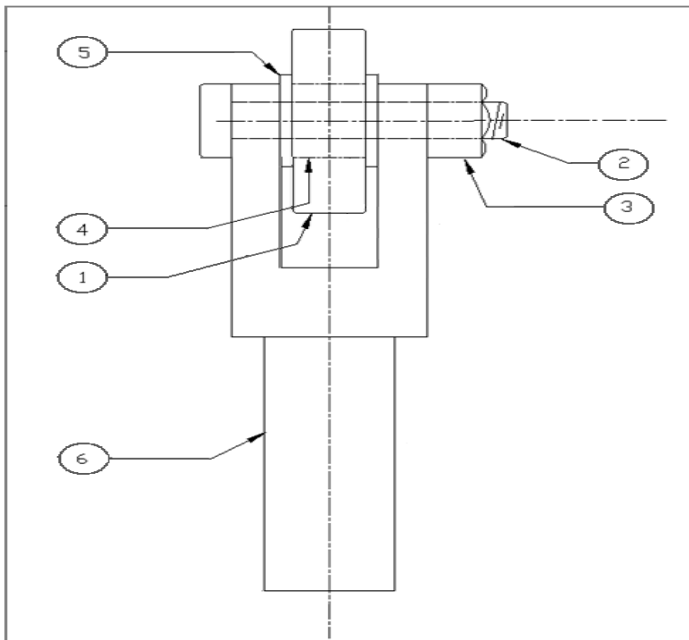
Roller burnishing tool

The properties of the ball and roller burnishing tools are shown in Table 1. A roller burnishing tool is designed

Table 1. Some properties of the burnishing tools

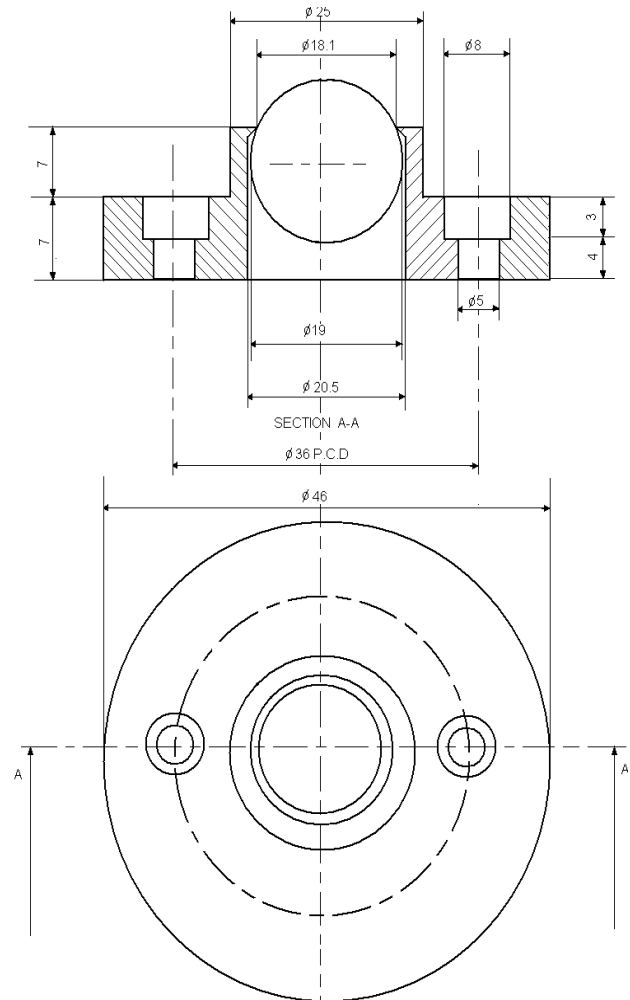
Burnishing tool	Ra (µm)	HRC
Ball	0.04	64
Roller	0.14	62

Fig. 4 Roller burnishing tool assembly



and fabricated as shown in Fig. 4. A roller of 40 mm diameter and 12 mm width is utilized for roller burnishing tool. The Roller burnishing tool assembly consists of the following parts. 1. Bush. 2. Special bolt 3. Nut 4. Roller 5. Washers 6. Shank. The shank of the roller burnishing tool is fixed in the dynamometer and it is tightened with

Fig. 5. Ball burnishing tool assembly.



two bolts. The chemical composition of the roller is: Fe 97.003, Si 0.18, Mn 0.26, Ni 0.12, Cr 1.44, C 0.99, S 0.007.

Ball burnishing tool

A ball burnishing tool is designed and fabricated. A 14 mm diameter ball is used in ball burnishing tool assembly. Fig. 5 shows the drawing of ball burnishing tool assembly. The detailed drawing of ball housing is shown in Fig. 6.

When the ball is pressed against the surface of the brass specimen, spring will be compressed, thus spring being used mainly to reduce the possible sticking of the tool onto the surface of the specimen.

The burnishing force is measured by a dynamometer. The parts of ball burnishing tool include: 1. Shank, 2. Special bolt, 3. Nut, 4. Roller, 5. Washers and 6. Bush. The shank of the ball burnishing tool is fixed in the dynamometer and it is tightened with two bolts.

Dry turning and dry burnishing are used in all the experimental work. But, petrol is used to clean the specimens before burnishing. Cleaning of the ball and roller is carried out continuously in order to prevent any hard particles from entering the contact surface between

the tool and the specimen. Such hard particles will create deep scratches, which may damage the burnished surface of the specimens.

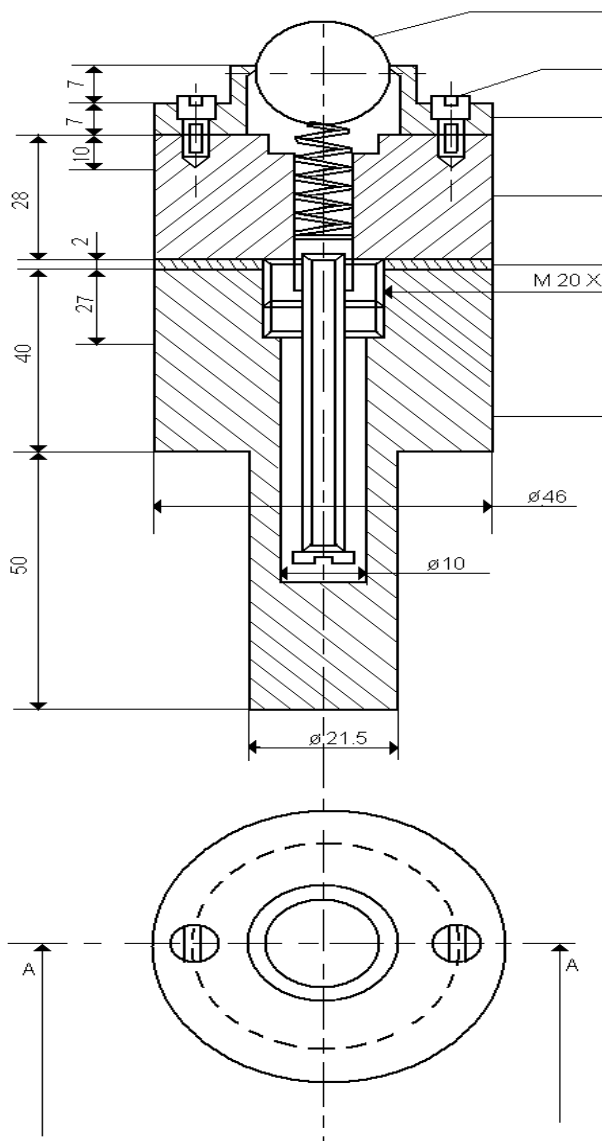
Table 2. Chemical composition of brass specimens (wt %)

Specimen	Al	Cu	Fe	Si	Zr	Sn	Pb	Ni
Brass	0.11	58.46	0.24	0.07	37.78	0.83	1.9	0.1

Machines and equipment

The machines and equipment utilized in the present experiments are: i. Lathe: PSG A 141 Lathe, PSG make, Coimbatore, India, ii. Surface Roughness Tester: Mitutoyo, Surf Test 211 model, Japan make and iii. Rockwell Hardness testing machine: FIE Hardness testing machine, Saroj Engineering Udyog Pvt. Ltd., Jaysingpur, India make.

Fig. 6. Detailed drawing of Ball housing.



Work piece

Commercially available brass is used in the present experimental work. Work piece diameter is 38 mm. The chemical composition of brass is shown in Table 2. Burnishing experiments are conducted on turned brass work piece, which is corrosive resistant, good conductor and available in the form of round bars. The brass work piece is specially fabricated and the dimensions are shown in millimeters (Fig. 7). Photograph of brass work piece for the ball and roller burnishing experiments is shown in Fig. 8.

Fig. 7. Specially fabricated Brass work piece.

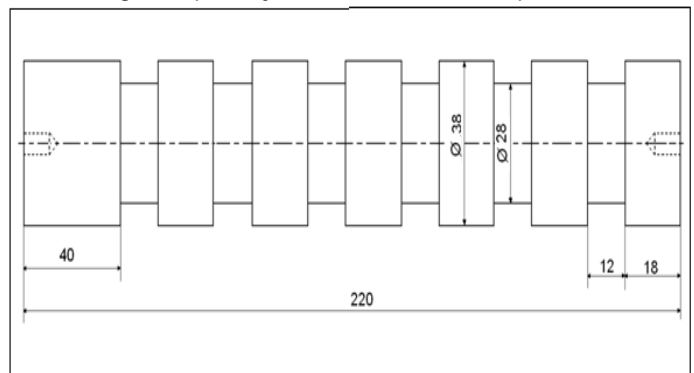


Fig. 8. Photograph of Brass work piece.



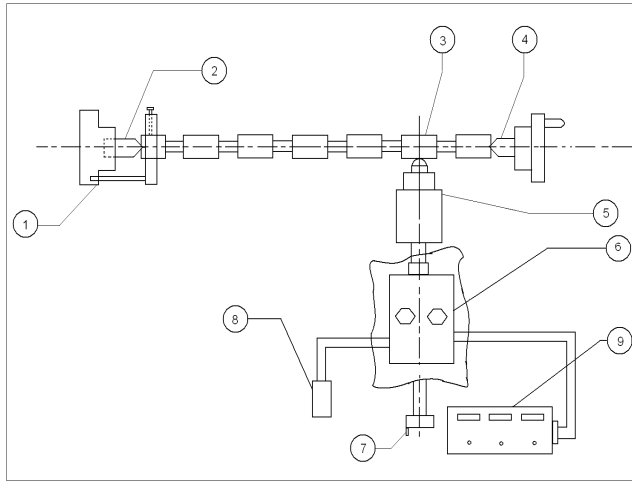
First, the work piece is held in 3- jaw chuck of lathe and facing operation is completed on both sides and centre drilling is completed on both the faces. Then, the work piece is held between centers of lathe and it is driven through the lathe dog. A high speed steel (H. S. S.) single point cutting tool is fixed in the tool post of the lathe and work piece is turned to have 6 steps and grooves in between them. In actual experiments, by applying different parameters on various steps, this long work piece can be utilized as 6 different work pieces.

Experimental setup

The Ball burnishing

The Ball burnishing tool is fixed in the dynamometer, which is mounted on the Lathe. The experimental set up with ball burnishing tool is shown in Fig. 9. It consists of the parts: 1. Three jaw chuck, 2. Live center, 3. Dead center, 4. Brass work piece, 5. Ball Burnishing tool, 6. Dynamometer fixed to the cross slide of Lathe, 7. Hand wheel for cross slide of lathe, 8. Input power to the Dynamometer, and 9. Strain reader.

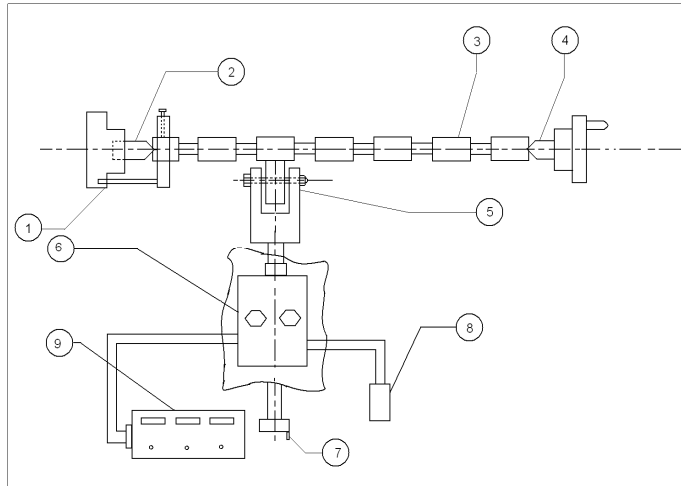
Fig..9. Experimental setup with Ball



The Roller burnishing

The Roller burnishing tool is fixed in the dynamometer, which is mounted on the Lathe. The experimental set up is shown in Fig. 10. It consists of the following parts: 1. Three jaw chuck 2. Live center 3. Brass work piece 4. Dead center 5. Roller Burnishing tool 6. Dynamometer fixed to the cross slide of Lathe 7. Hand wheel for cross slide of lathe 8. Input power to the Dynamometer and 9. Strain reader.

Fig. 10. Experimental set up with Roller burnishing tool.



Photograph of the experimental set up of Roller burnishing process with brass work piece on lathe is shown in Fig. 11. In the present work, roller having outside diameter of 40 mm is used for roller burnishing. The tool post and compound rest are removed from the lathe. Dynamometer together with its fixture is held on the cross slide of PSG A 141 lathe, PSG make, Coimbatore, India and it is tightened with fixing bolt. The roller burnishing tool assembly is mounted in the tool holder of dynamometer and it is held rigidly by two bolts. Burnishing force i.e., radial component of cutting force (in y- direction) is measured by dynamometer. The

Fig. 11. Photograph of experimental set up of Roller burnishing process with brass work piece on PSG lathe.



dynamometer, Roller burnishing tool, brass work piece, etc. are shown in the close up view clearly in Fig. 12.

Fig12 Photograph showing close up view of brass work piece with roller burnishing tool on lathe.



Measurement of surface roughness values

A repetitive or random deviation from the nominal surface which forms the pattern of the surface is known as surface texture. It includes roughness, waviness, flaws, etc. Waviness is due to the geometric errors of

Fig.13.Measurement of Surface Roughness on Brass Specimen.



machine tool and varying stiffness of the machine tool. Roughness is due to the inherent kinematic differences of the cutting process.

Various parameters of surface roughness i. e. R_a , R_z , R_{max} are measured by using Surface Roughness Tester - 211 Mitutoyo, Japan make, as shown in Fig. 13. Centre line average (C. L. A.) or R_a value is the arithmetic average roughness height. Average height difference between the five highest peaks and five lowest valleys within the traversing length are called peak to valley height (R_z).

Experiments with roller burnishing tool on brass work piece

Experiment No. 1: Influence of number of burnishing tool passes on surface roughness (R_a)

In the beginning, the first step of the brass specimen, i.e., the step near the dead centre is finished with ball burnishing tool one time by keeping the burnishing force, feed rate and burnishing speed constant. Here, $V= 20.1 \text{ m min}^{-1}$, $f= 0.060 \text{ mm rev}^{-1}$, $d_b= 12 \text{ mm}$ and $d_r= 40 \text{ mm}$. After that, the second step is finished two times, the third step three times, and the finishing process by ball burnishing tool is continued up to six steps. Corresponding surface roughness values (R_a) are measured on all these steps on the brass work piece, as shown in Table 3.

Table 3. Effect of the number of burnishing tool passes on the surface roughness of brass specimen by ball burnishing.

S. No.	1	2	3	4	5
Surface roughness $R_a \mu\text{m}$	1.95	1.24	0.76	0.51	0.62

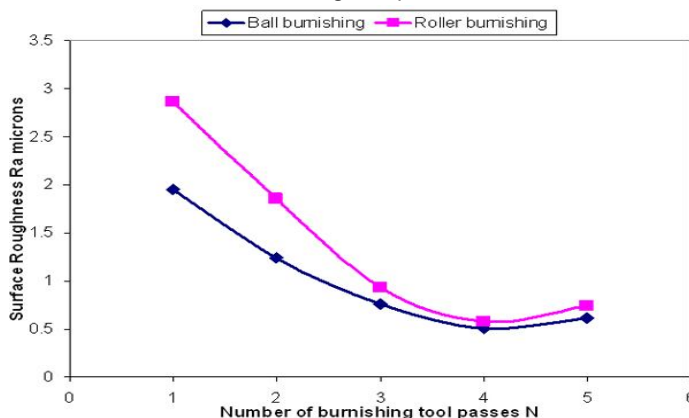
Initial surface roughness, $R_{ai} = 3.96 \mu\text{m}$.

Table 4. Effect of burnishing force on the surface roughness of brass specimen by roller burnishing.

S. No.	1	2	3	4	5
Surface roughness $R_a \mu\text{m}$	2.87	1.86	0.93	0.58	0.74

Initial surface roughness, $R_{ai} = 3.96 \mu\text{m}$.

Fig. 14 Variation of surface roughness with number of burnishing tool passes.



Later on, ball burnishing tool is removed from the dynamometer and the roller burnishing tool is fixed to the dynamometer. The first step of the brass specimen, i.e., the step near the dead centre is finished with roller burnishing tool one time by keeping the burnishing force, feed rate and burnishing speed constant. Here, $V= 20.1 \text{ m min}^{-1}$, $f= 0.060 \text{ mm rev}^{-1}$, $d_b= 12 \text{ mm}$ and $d_r= 40 \text{ mm}$. Again, the second step is finished two times, the third step three times, and the finishing process by roller burnishing tool is continued up to six steps. Corresponding surface roughness values (R_a) are measured on all these steps of the brass specimen, as shown in Table 4. A graph is drawn between number of burnishing tool passes and surface roughness R_a , for both ball burnishing and roller burnishing experiments as shown in Fig. 14.

Experiment No. 2: Variation of surface hardness (HRB) with number of burnishing tool passes

Initially, the first step of the brass specimen, i.e., the step near the dead centre is finished with ball burnishing tool one time by keeping the burnishing force, feed rate and burnishing speed constant. After that, the second step is finished two times, the third step three times, and the finishing process by ball burnishing tool is continued up to five steps. Corresponding surface hardness (HRB) values are measured on all these steps on the brass work piece, as shown in Table 5.

Table 5. Effect of number of burnishing tool passes on the surface hardness of brass specimens by ball burnishing.

S. No.	1	2	3	4	5
Surface hardness HRB	65	70	75	80	85

Initial surface hardness, $HRB_i = 63$

Later on, the different steps of the brass specimen are finished with roller burnishing tool by changing the number of burnishing tool passes. The final surface hardness values (HRB) are measured on all these steps, as shown in Table 6. A graph is drawn between number of burnishing tool passes and surface hardness, for both ball burnishing and roller burnishing experiments as shown in Fig. 15.

Table 6. Effect of burnishing force on the surface hardness of brass specimen by roller burnishing.

S. No.	1	2	3	4	5
Surface hardness HRB	67	71	75	79	83

Initial surface hardness, $HRB_i = 63$

Result and discussion

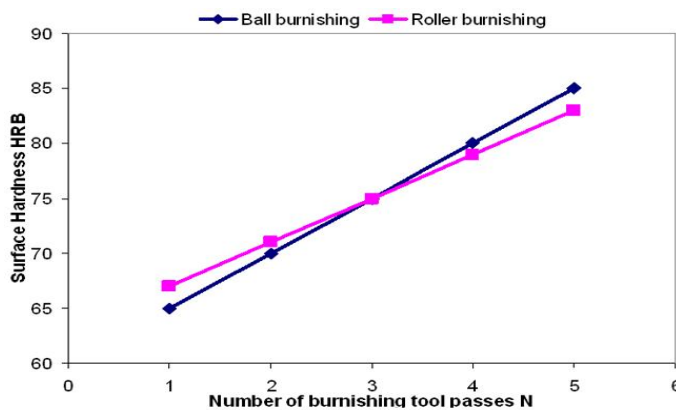
Influence of number of burnishing tool passes on surface roughness

Fig. 14 shows the influence of the number of burnishing tool passes on surface roughness for both ball and roller burnished brass specimens. It is observed from the graphs that the surface roughness decreases with the increase in number of burnishing tool passes up to a minimum value. After that, the surface roughness

increases with the increase in number of burnishing tool passes. This minimum value of surface roughness for brass material is nearly same for both ball and roller burnishing and it occurs at the fourth pass in both figures. It may be noted that the burnishing force is greater in roller burnishing when compared to that in ball burnishing.

The reason is explained below. In each tool pass, the tool is being applied under a constant burnishing force to the plastically deformed surface of the previous pass. Similarly, to the effect of burnishing force, after a particular number of passes, the surface layer becomes highly work hardened, causing flaking to occur. This will lead to the deterioration of the surface and an increase in the surface roughness.

Fig. 15 Variation of surface hardness with number of



Influence of number of burnishing tool passes on surface hardness

Fig. 15 shows the influence of the number of burnishing tool passes on the surface hardness, for both ball and roller burnished brass specimens. It is inferred from the curves that the surface hardness on brass specimens increases with the increase in the number of tool passes for both ball and roller burnishing processes. Also, it is noted from the curves that the increase in surface hardness improvement is more after three passes, for ball burnished brass specimens. It is observed from the above figure that the force for roller burnishing is greater than that for ball burnishing.

It is noted from Fig. 15 that the surface hardness increases with the increase in the number of burnishing tool passes, as the metallic surface is continuously deformed with the increase in this burnishing parameter. It should be mentioned here that the increase in surface hardness will level off at high values of number of

burnishing tool passes or burnishing force. This is because all metals will have a definite capacity for cold working. When this capacity exceeds further, considerable cracks will be developed within the surface of the metal and failure will occur.

Conclusions

After conducting the experimental investigation using Ball and Roller burnishing tools with brass work piece on PSG A 141 lathe, the following conclusions are obtained, with the conditions mentioned above. The surface roughness decreases to a minimum value with the increase in the number of burnishing tool passes, in both ball and roller burnishing processes. After attaining a minimum value, it starts to increase with number of burnishing tool passes.

The surface hardness increases with the increase in number of burnishing tool passes in both ball burnishing and roller burnishing. It is observed that the surface roughness is lower and surface hardness is greater in Ball burnishing when compared to that in roller burnishing, even when the burnishing force of the ball burnishing is less.

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