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The effects of ball- and roller-burnishing on the surface roughness and hardness of some non-ferrous metals

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Abstract

Simple ball- and roller-burnishing tools were used for the experimental work of the present study, these tools being quite similar in their design principles. The performance of the tools, together with the effects of the burnishing force and the number of burnishing tool passes on the surface roughness and surface hardness of commercially available aluminum and brass, were studied. The results show that improvements in the surface roughness and increases in the surface hardness were achieved by the application of both ball burnishing and roller burnishing with the non-ferrous metals under consideration. © 1997 Elsevier Science S.A.

Keywords: Ball-burnishing; Roller-burnishing; Non-ferrous metals

1. Introduction

Burnishing is considered as a cold-working finishing process, differing 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 [1]. Accordingly, burnishing distinguishes itself from chip-forming finishing processes such as grinding, honing, lapping and super-finishing which induce residual tensile stresses at the machined surface layers [2]. Also, burnishing is economically desirable, because it is a simple and cheap process, requiring less time and skill to obtain a high-quality surface finish [3].

The burnishing process can be achieved by applying a highly polished and hard ball or roller onto a metallic surface under pressure. This will cause the peaks of the metallic surface to spread out permanently, when the applied burnishing pressure exceeds the yield strength of the metallic material, to fill the valleys, see Fig. 1 [4]. The surface of the metallic material will be smoothed out and because of the plastic deformation the surface becomes work hardened, the material being left with a residual stress distribution that is compressive on the surface, see Fig. 2 [1]. The changes in surface characteristics due to burnishing will cause improvements in surface hardness, wear resistance, fatigue resistence, yield and tensile strength and corrosion resistance, as claimed by many authors [5–8]. A typical experimental set-up for ball- and roller-burnishing is illustrated in Fig. 3. It can be seen from this figure that the ball or roller rotates by the effect of frictional engagement between the surface of the ball or roller and the surface of the workpiece.

The present work is an attempt to study the effects of both ball- and roller-burnishing on the surface roughness and hardness of two non-ferrous materials, namely

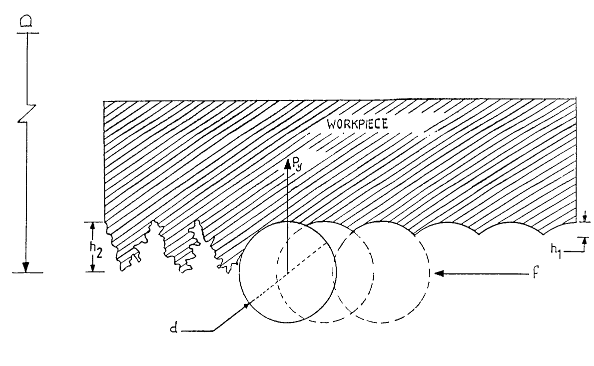

Fig. 1. The burnishing process [4].

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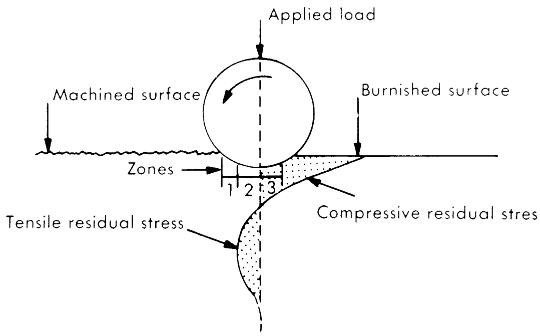

Fig. 2. Schematic representation of the residual stress distribution in the burnishing process [1].

aluminum and brass. The variable burnishing parameters selected for the experimental work were the burnishing force and the number of burnishing tool passes, with the other burnishing parameters such as feed-rate, speed etc. being kept constant. These selected burnishing parameters, as has been shown by AL-Bsharat [9], are the most effective parameters in the ball burnishing process. Recently, these findings have been confirmed in roller burnishing by AL-Wahhab [10].

2. Materials and equipment

2.1. Materials

Commercial aluminum and brass were used in the experiments, supplied as 32 mm diameter bars, the chemical compositions are shown in Table 1.

Appropriate specimens were cut from these bars to an approximate length of 300 mm using a sawing machine, then each specimen was turned to a diameter of 28 mm and divided into several regions, some of these regions being used for ball burnishing and others for roller burnishing. One region was left unburnished (only turned) for initial surface roughness and hardness measurements.

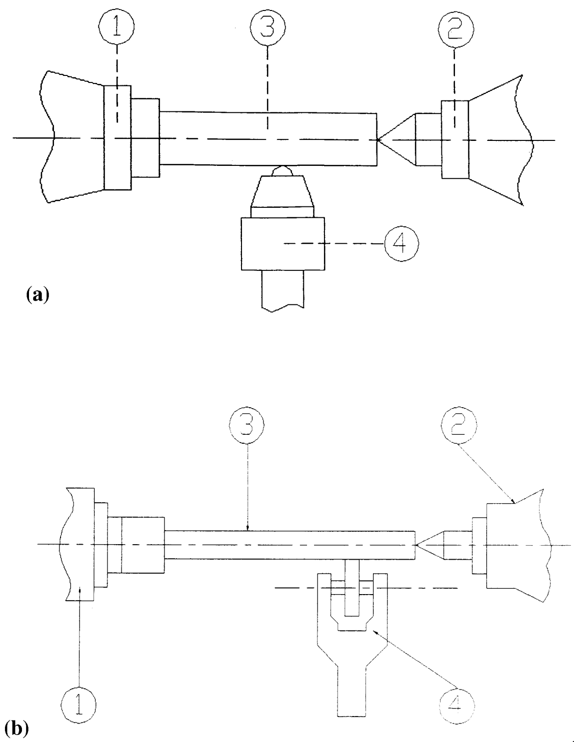

Fig. 3. Typical experimental set-up for: (a) Ball burnishing; (b) roller burnishing. (1) headstock; (2) tailstock; (3) workpiece; (4) burnishing tool.

2.2. Burnishing tools

A 10 mm diameter ball and a 13 mm diameter roller of 5 mm width were used for burnishing. The chemical compositions and some properties of the ball and roller are shown in Tables 2 and 3, respectively. The detailed and assembly drawings are shown in Fig. 4 for the ball-burnishing tool and in Fig. 5 for the roller-burnishing tool. When the ball or roller is pressed against the surface of the metallic specimen, a precalibrated spring will be compressed, this spring being used mainly to reduce the possible sticking of the tool onto the surface

Table 1
Chemical composition of the specimens (wt.%)

Specimen	Al	Cu	Fe	Si	Mn	Zn	Sn	Pb	Ni
Brass	0.11	58.46	0.24	0.07	—	37.78	0.83	1.9	0.1
Aluminum	Remainder	5.34	0.3	0.05	0.55	0.03	—	—	—

Table 2
Chemical compositions of the burnishing tools (wt.%)

Burnishing tool	Fe	Si	Mn	Ni	Cr	C	S
Ball	Remainder	0.23	0.29	0.25	1.44	0.99	0.006
Roller	Remainder	0.18	0.26	0.12	1.44	0.99	0.007

Table 3
Some properties of the burnishing tools

Burnishing tool	R_a (μm)	HRC
Ball	0.012	63
Roller	0.12	61

of the specimen and also to measure the applied burnishing force. The shanks of both burnishing tools are designed in such a manner that each of them can be simply mounted or fixed onto the tool holder of a machine tool such as a lathe or a shaping machine, etc. More details about these tools can be found in Ref. [9] for the ball-burnishing tool and in Ref. [10] for the roller-burnishing tool.

2.3. Machines and equipment

The following machines and equipment were used throughout the experimental work: (i) A Colchester master 2500 lathe; (ii) a Surtronic 3 P instrument for surface roughness (R_a) measurement; and (iii) a Rockwell hardness testing machine (Model 855A).

3. Experimental details and results

After turning the specimens to a diameter of 28 mm on the Colchester lathe, the cutting tool was replaced by the ball or roller burnishing tool to enable the burnishing process to be carried out on the specimens using the same lathe. The set-up for the burnishing processes used is shown in Fig. 3. Dry turning and burnishing were used in all the experimental work, but alcohol was used to clean the specimens before burnishing. Cleaning of the ball or roller was carried out continuously in order to prevent any hard particles from entering the contact surface between the tool and the specimen, such hard particles usually leaving deep scratches, which may damage the burnished surface of the specimen.

3.1. Surface roughness

3.1.1. Effect of the burnishing force

Figs. 6 and 7 show the effect of burnishing force on surface roughness of ball- and roller-burnished aluminum and brass specimens, respectively. It can be seen from the curves of these figures, that the surface roughness decreases with the increase in burnishing force to a minimum value, after which it starts to increase. This minimum value for both of the materials considered is lower in ball burnishing than it is in roller burnishing, although the burnishing forces are greater in the latter process.

3.1.2. Effect of the number of burnishing tool passes

The effect of the number of tool passes on surface roughness for both ball- and roller-burnished aluminum and brass specimens is illustrated in Figs. 8 and 9,

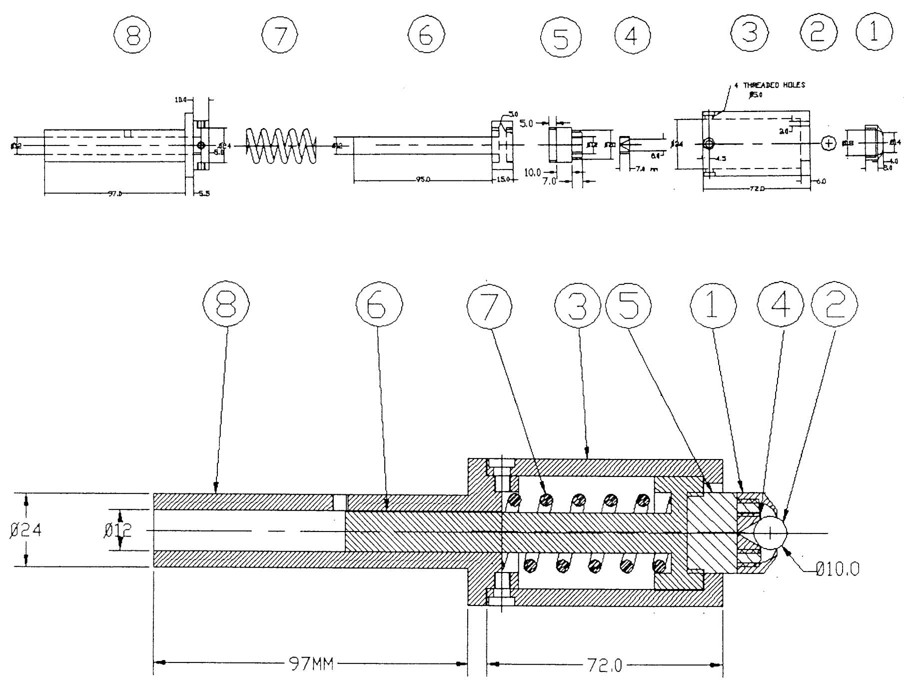

Fig. 4. Detailed and assembly drawings of the ball-burnishing tool [9]. (1) adapter cover; (2) burnishing ball; (3) casing; (4) burnishing ball seat; (5) adapter; (6) spring seat; (7) calibrating spring; (8) shank.

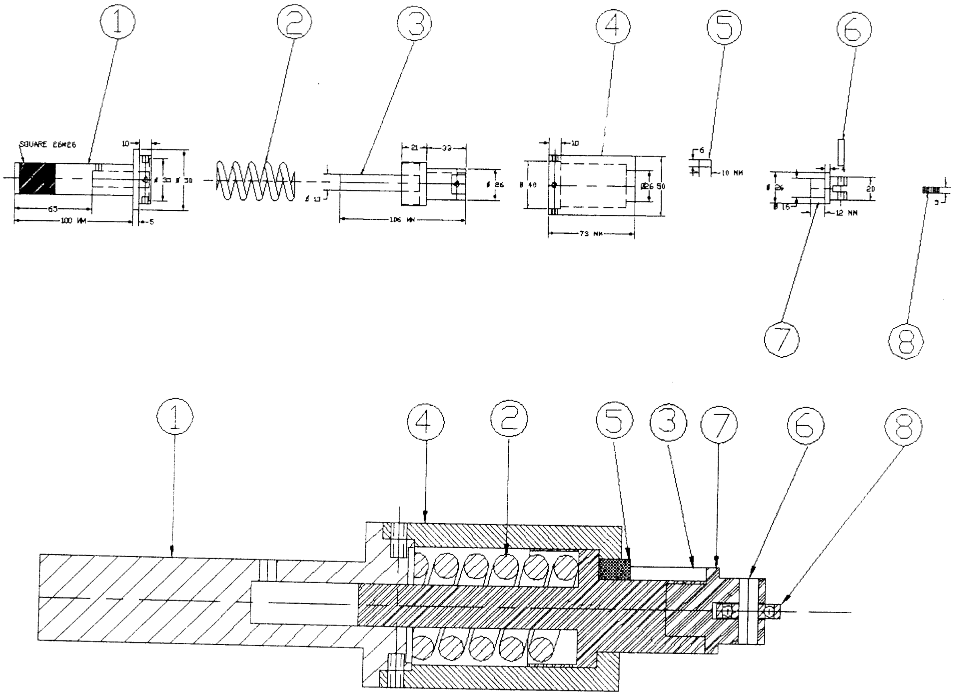

Fig. 5. Detailed and assembly drawings for the roller-burnishing tool [10] (1) shank; (2) calibrating spring; (3) tool stem; (4) casing; (5) key; (6) pin; (7) roller holder; (8) burnishing roller.

respectively. Each curve in these figures indicates that the surface roughness reaches a minimum value with increase in the number of burnishing tool passes, after which it starts to increase with further increase in the number of passes. This minimum value is nearly the same for ball- and roller-burnishing and it occurs at the fourth pass in both figures, although the force in roller burnishing is greater than that in ball burnishing.

3.2. Surface hardness

3.2.1. Effect of burnishing force

Figs. 10 and 11 show the effect of burnishing force on the surface hardness of aluminum and brass specimens, respectively. It seems that surface hardness increases with increase in the ball- and roller-burnishing force for both of the materials under consideration. It can be observed also from each of these figures that the surface-hardness increase is greater in ball burnishing than it is in roller burnishing, although the forces are greater in roller burnishing.

3.2.2. Effect of the number of burnishing tool passes

The effect of the number of tool passes on the surface hardness, for both ball- and roller-burnished aluminum and brass specimens is shown in Figs. 12 and 13, respectively. It can be observed from these figures that the surface hardness increases with the increase in the number of tool passes for both ball-burnished and roller-burnished aluminum and brass specimens. However, the increase in surface hardness is greater beyond five passes for ball-burnished aluminum specimens (Fig. 12) and beyond three passes for ball-burnished brass specimens (Fig. 13). It is noted that the force for roller burnishing is greater than that for ball burnishing in both figures.

4. Discussion

4.1. Surface roughness

4.1.1. Effect of burnishing force

It can be observed from Figs. 6 and 7 that the surface roughness decreases to a minimum value then starts to increase with increase in the burnishing force. As this force increases, the penetration depth of the ball or roller inside the metallic surface will be increased, leading to a smoothing-out of the metallic surface (Fig. 14(a)), until this surface starts to show some deterioration, the latter being caused by the flaking of the surface due to the high work-hardening induced into the surface by the increase in the amount of plastic deformation as the burnishing force increases. When such deterioration of the surface occurs, the surface roughness of the specimen starts to increase.

The contact surface area between the tool and the specimen is smaller in ball burnishing than in roller burnishing under the same burnishing force. This means that the ball will penetrate inside the metallic surface deeper than the penetration of the roller. Relating this to the above discussion, an explanation can be given as to the cause of the lower surface roughness obtained by ball burnishing in comparison with that for roller burnishing, even when the burnishing force used in ball burnishing is smaller than that in roller burnishing.

4.1.2. Effect of the number of burnishing tool passes

From the curves in Figs. 8 and 9, it can be seen that a reduction in surface roughness is achieved up to the first four passes in both figures, but that beyond this number of tool passes the surface roughness starts to increase. In each pass, the tool is being applied under a constant burnishing force to the plastically-deformed surface of the previous pass (Fig. 14(b)). 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.

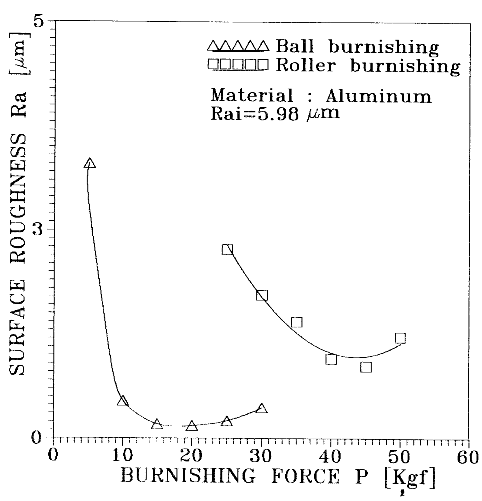

Fig. 6. Effect of the burnishing force on the surface roughness of aluminum. Burnishing conditions: $V = 20.23$ m min^{-1}; $f = 0.1$ mm rev^{-1}; $N = 1$; $d_b = 10$ mm; $d_r = 13$ mm (1 kgf = 9.81 N).

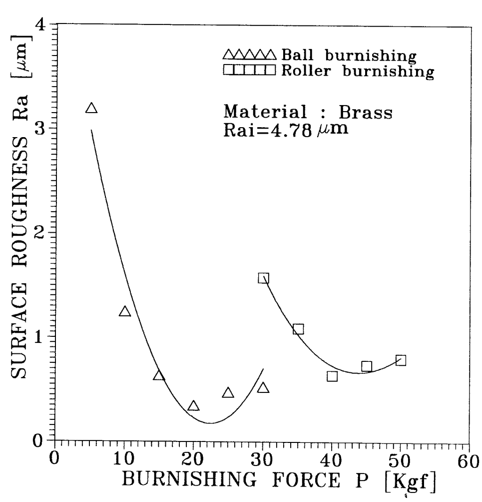

Fig. 7. As for Fig. 6, but for brass.

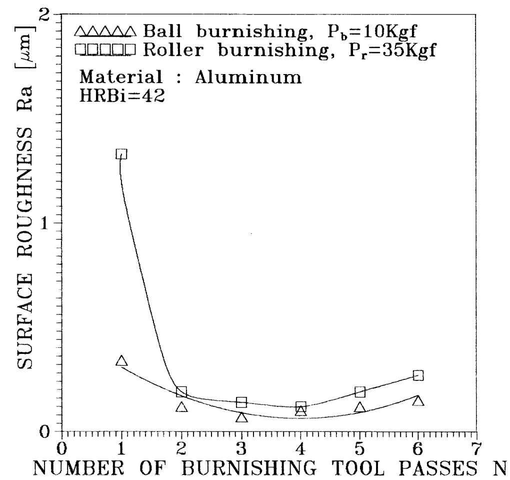

Fig. 8. Effect of the number of burnishing tool passes on the surface roughness of aluminum. Burnishing conditions: $V = 20.23$ mm min^{-1}; $f = 0.1$ mm rev^{-1}; $d_b = 10$ mm; $d_r = 10$ mm.

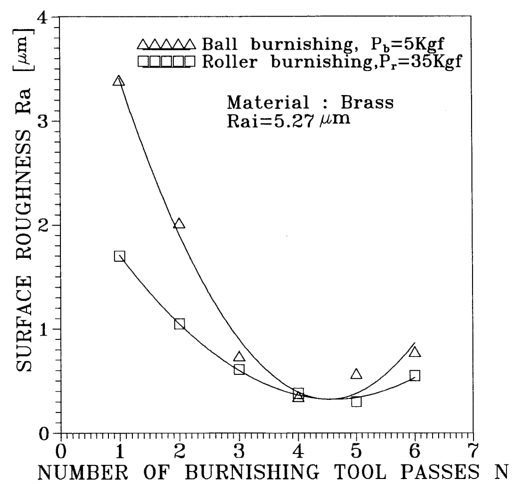

Fig. 9. As for Fig. 8, but for brass.

4.2. Surface hardness

4.2.1. Effect of the burnishing force

The increase in the burnishing force will increase the plastic deformation, as the penetration of the ball or roller will be increased. This will lead to an increase in the internal compressive residual stresses, which in turn causes a considerable increase in surface hardness, as can be observed from Figs. 10 and 11. The difference between the increase in surface hardness of ball- and roller-burnishing is due to the difference in penetration of each tool inside the metallic surface. Under constant burnishing force, the ball can penetrate the metallic surface deeper than does the roller, causing a greater amount of plastic deformation to occur, due to the small contact surface area between the ball and the specimen, as was discussed earlier.

4.2.2. Effect of the number of burnishing tool passes

The surface hardness increases with the increase in the number of burnishing tool passes (Figs. 12 and 13), 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 has a definite capacity for cold working. When this capacity is exceeded, considerable cracks will be developed within the surface of the metal and failure will occur.

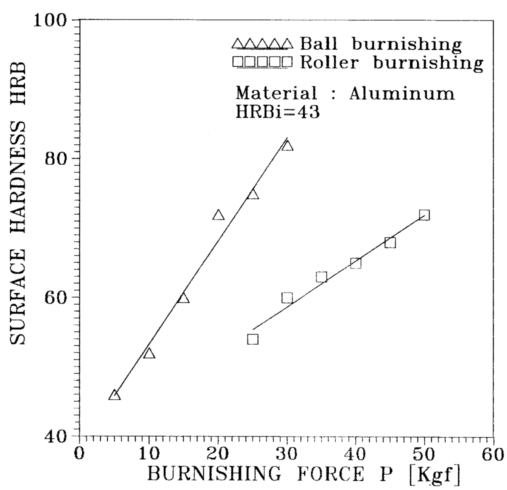

Fig. 10. The effect of the burnishing force on the surface hardness of aluminum. Burnishing conditions: $V = 20.23$ mm min^{-1}; $f = 0.1$ mm rev^{-1}; $N = 1$; $d_b = 10$ mm; $d_r = 13$ mm.

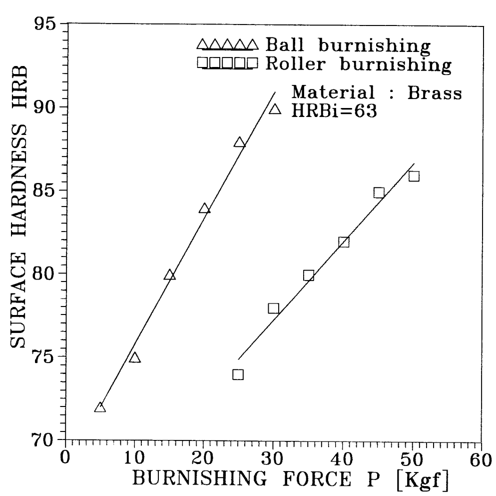

Fig. 11. As for Fig. 10, but for brass.

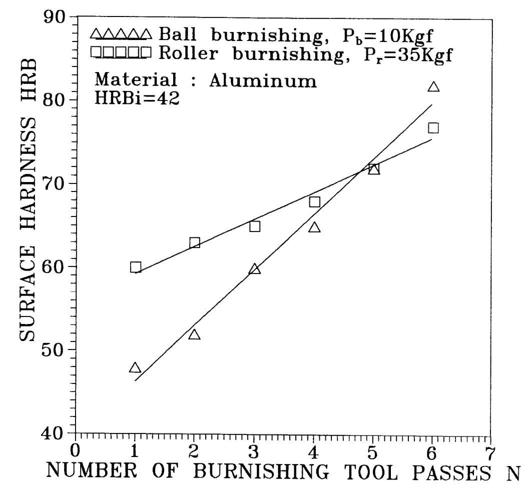

Fig. 12. The effect of the number of burnishing tool passes on surface hardness of aluminum. Burnishing conditions: $V = 20.23$ mm min^{-1}; $f = 0.1$ mm rev^{-1}; $d_b = 10$ mm; $d_r = 13$ mm.

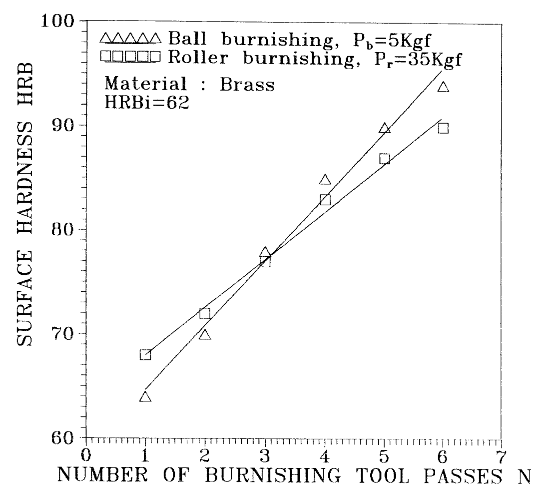

Fig. 13. As for Fig. 12, but for brass.

5. Conclusions

Under the considered burnishing conditions of the above described experimental work, the following conclusions can be drawn.

(1) In both ball- and roller-burnishing, the surface roughness decreases to a minimum value with the increase in burnishing force and the number of burnishing tool passes, then it starts to increase with each of these burnishing parameters.

(2) In both ball- and roller-burnishing, the surface hardness increases with the increase in burnishing force and number of burnishing tool passes.

(3) Ball burnishing seems to give lower surface roughness and greater surface hardness than roller burnishing, even when the burnishing force of the former is smaller.

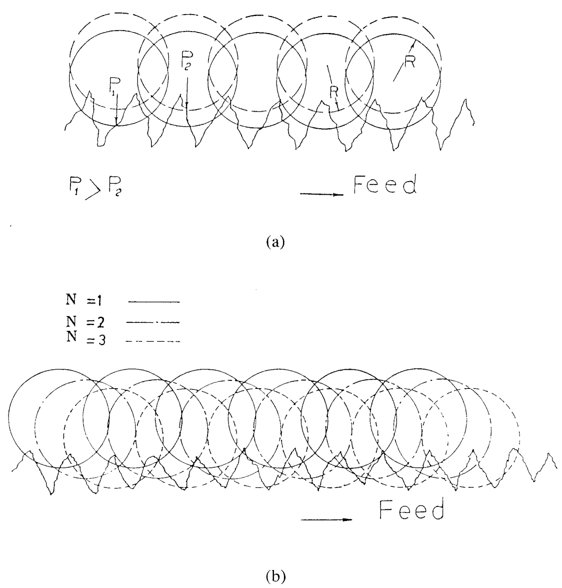

Fig. 14. Schematic representation showing the effect of changing: (a) The burnishing force; and (b) the number of burnishing tool passes.

6. Nomenclature

P_b	burnishing force normal to the specimen axis in ball burnishing (kg f)
P_r	burnishing force normal to the specimen axis in roller burnishing (kg f)
N	number of burnishing tool passes
d_b	burnishing ball diameter (mm)
d_r	burnishing roller diameter (mm)
f	burnishing feed (mm rev^{-1})
V	burnishing speed (m min^{-1})
HRB	Rockwell hardness (B) scale
HRB_i	initial Rockwell hardness (B) scale of the unburnished (turned) specimen
R_a	arithmetical surface roughness average (μm)
R_{ai}	initial arithmetical surface roughness average of the unburnished (turned) specimen (μm)

References

[1] C. Wick, R.F. Veilleux, Tool and manufacturing engineers handbook, Soc. Manuf. Eng. 3 (1985) 16–38.
[2] T. Siva Prasad, B. Kotiveerachari, External burnishing of aluminum components, J. Inst. Eng. India 69 (1988) 55–58.
[3] N.H. Loh, S.C. Tam, S. Miyazawa, Application of experimental design in ball burnishing, Int. J. Mach. Tools Manuf. 33 (1993) 841–852.
[4] A.M. Hassan, A.S. AL-Bsharat, Influence of burnishing process on surface roughness hardness and microstructure of some non-ferrous metals, Wear 199 (1996) 1–8.
[5] A.M. Hassan, A.S. AL-Bsharat, Improvement in some properties of non-ferrous metals by the application of ball burnishing process, J. Mater. Process. Technol. 59 (3) (1996) 250–256.
[6] R.L. Murthy, B. Kotiveerachari, Burnishing of metallic surfaces—a review, Prec. Eng. 3 (1981) 172–179.
[7] R. Rajasekariah, S. Vaidyanathan, Increasing the wear–resistance of steel components by ball burnishing, Wear 34 (1975) 183–188.
[8] Yu.G. Shneider, Characteristics of burnished components, Mach. Tooling 38 (1) (1967) 19–22.
[9] A.S.H. AL-Bsharat, Investigation into the effect of burnishing process on some properties of cylindrical metallic materials, MSc Thesis, Jordan University of Science and Technology, Jordan, 1994.
[10] O.M. Abd AL-Wahhab, The effects of roller-burnishing on some properties of non-ferrous metals, MSc Thesis, Jordan University of Science and Technology, Jordan, 1996.