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Effect of Feed Rate and Constant D.O.P. by Burnishing Process on Non-Ferrous Metals

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Abstract— **Burnishing is a metal compression process to get smooth surface without material removal and it is cold working process. Ball burnishing produces smooth surface on flat and round parts. Burnishing process produces work hardened sub surface by plastic deformation of surface irregularities. The burnishing process is carried by pressing hard freely rotating spherical balls or cylindrical roller into a surface of the metal desired. The surface roughness is produced by planetary rotation of ball / roller. The resulting cold working process produces smooth surface, compress the surface to induce compressive strength, to resist wear, to improve corrosion resistance and improved fatigue life. The operating parameters are spindle speeds, feed rate and depth of penetration. The research paper presents for vertical burnishing on commercially available Copper and Aluminum metal. From the research, it was concluded that high feed arte produces smooth surface and hard sub-surface and unable to achieve desired level due to limitation.**

Keywords— **Ball and roller burnishing, depth of penetration, Plastic deformation, Surface roughness**

I. Introduction

There are many metal finishing process used to produce surfaces with high quality textures. The process could be classified into chip removal process such as grinding, turning, milling, shaping and slotting etc. and chip less process, such as burnishing [1-3]. Conventional machining processes such as milling and turning produce a surface with inherent irregularities, finishing processes such as grinding, lapping, polishing, and honing commonly being employed to improve the surface finish. The burnishing process gives many advantages in comparison with chip-removal processes. Burnishing increases the surface hardness of the work piece, which in turn improves wear resistance increases corrosion resistance, improves tensile strength, maintains dimensionalstability and improves the fatigue strength by inducing residual compressive stresses in the surface of the work piece [4–7]. Seemikeri et al. [8] refereed in their research paper burnishing is well-known to impart deep compressive residual stress in the subsurface that is beneficial to fatigue performance. Fig.1. shows principle on which roller or ball burnishing works. The ball-burnishing process increases the surface finish and the surface hardness of non-ferrous metals to certain limits. Since the increase in these characteristics improves the wear resistance of materials, it can be stated that the use of the ball burnishing process increases the wear resistance of brass components [9]. M.H. El-Axira,et al. [10] conducted study on Aluminum 2014 and found that burnishing speed has different effect on the two responses studied. An increase in burnishing speed leads to a considerable reduction in out-of-roundness, however, it has no significant effect on surface micro-hardness. The recommended burnishing feeds that result in high surface micro-hardness and a considerable reduction in out of- roundness are in the range from 0.2 to 0.35mm/rev. The burnishing speed, feed, burnishing force and number of passes are the influencing parameters on the final quality of the components, namely the surface finish [11]. M.H. El-Axira ET AL. [12] conducted burnishing process for inner surface and found that number of passes interacts with both burnishing speed and burnishing feed, number of passes with low burnishing speed and/or high. SThamizhmanii et al. [13] the surface roughness has increased as the spindle rotation, feed and depth of penetration increased for aluminium, brass and copper. If the over lapping of the roller is maintained, and then it is possible to achieve lower surface roughness value. SThamizhmanii et al. [14] conducted experiments the burnishing process on difficult to cut metals like Titanium alloy by applying suitable process parameters. It was found that surface hardness also increased as the spindle speed, feed rate and depth of penetration was increased. A higher surface hardness value obtained at 1400 spindle rotation with 300 feed rate and 0.35 mm depth of penetration.

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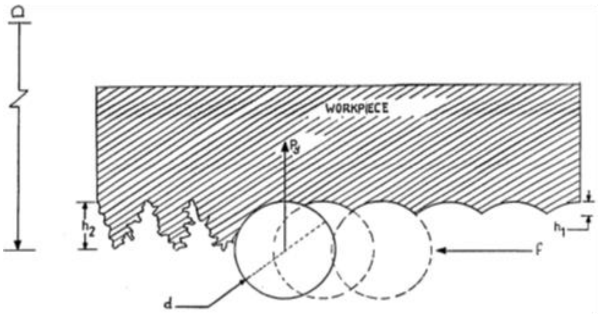
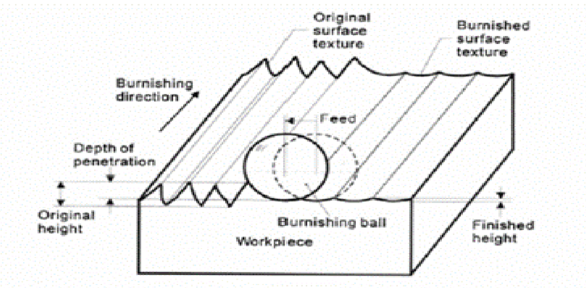
II. Benefits of Roller / Ball Burnishing Processes

Burnishing imparts a high finish to any machinable metals. Surfaces that are produced by boring operation or reamed or turned up to 3 microns or more can be finished to 0.05 to 0.20 microns in one pass at feed rates ranging from 150 to 3000 mm / minutes. Burnishing replaces grinding, lapping and other expensive secondary operations which eliminates extra parts handling and additional machines. Tool marks are rolled out, grain structured is condensed, and refined and compacted surface is smoother, harder and longer wear than ground or honed surfaces. Rolling action greatly reduces surface porosity, pits and scratches which could hold reactive surfaces or contaminates. As a result the corrosion resistance of burnished surface is higher than the open surfaces produced by grinding or honing. Due to plastic deformation, residual compressive stresses are induced in the surface. The compression greatly increases the fatigue properties of the components. Thousands of part can be finished with little or no burnishing tool wear. Setting up the burnishing tool takes less than a minute. Unskilled operators can produce close tolerance. The power requirement for burnishing is low due to the small amount of torque generated and inventory on tool is also low. Mirror finish in one pass, accurate sizing, close tolerances, eliminates lapping & honing, improved metallurgical properties - work hardened surface, increase in fatigue strength, no additional machine investment - attachable to any standard machine tool already present in the shop long tool life no operator skill required low torque & power requirements maximum parts interchangeability [15].



(a).Burnishing process [3]



(b). Generation of surface by roller or ball

Fig.1. (a).Burnishing process [3], (b). Generation of surface by roller or ball.

III. EXPERIMENTAL PROCEDURES

A multi roller burnishing tool are hardened rollers fitted in a housing and are rotates freely in a horizontal axis. The rollers project by 1 mm from housing surface. The tool used has 8 rollers. Fig.1 (a) and (b) show principle operation of burnishing process and generation of smooth surface. Fig.2 shows multi roller burnishing tool used for conducting experiments. The material used for burnishing are commercially available aluminum and copper. The size of the materials is 45 x 45 mm and 75 mm long. All the surfaces are machined by milling process in copper and aluminum metal. The surface roughness and surface hardness in copper metal was before burnishing was 4.5 micron and 109 BHN respectively. The surface roughness and hardness of aluminum was 4.7 micron and 107 BHN respectively. Table 1 give the operating parameters used to carry out research. The depth of penetration was kept as constant 0.50 mm. Three passes of burnishing process was carried out and surface roughness and surface hardness was measured in each pass for both metal. The surface roughness was measured by Mitutoyo surface SJ 400 tester and surface hardness by Vickers hardness tester.

Fig.2. Multi-roller vertical burnishing tool

TABLE I
OPERATING PARAMETERS

Feed rate mm/ min.	Spindle rotation - RPM	Depth of penetration as constant in mm
100	700, 1200, 1700, 2200	0.50
200	700, 1200, 1700, 2200	0.50
300	700, 1200, 1700, 2200	0.50
400	700, 1200, 1700, 2200	0.50

IV.RESULTS AND DISCUSSION

A. Surface roughness

Surface roughness is measure of smoothness in any machining process. The performance of machined component is depends upon the surface roughness and failure may occur due the roughness surface. Figure 3 (a) to (d) shows surface roughness plotted against feed rate Vs surface roughness obtained. Fig.3 (a) shows the roughness produced at 700 spindle rotation with constant depth of penetration at feed rate of 100, 200, 300 and 400 mm/ rev. The roughness as machined in copper was 0.21 micron. In pass 1, the feed rate was low of 100 mm/rev. the surface roughness was high in copper and aluminum metal. At pass 1, high roughness value was 0.26 microns at feed rate of 100 mm/rev. and correspondingly there was reduction in the roughness ranging from 0.26 microns to 0.17 microns in copper metal. As the tool pass 2 and pass 3 at feed rates to 200, 300 and 400 mm /rev., there was high reduction values from 0.24 microns to 0.17 microns in pass 2 and in the pass 3, surface reduction was 17 microns at end of pass 3. In every pass 1, 2, and 3, reduction in surface roughness vary from 19 % to 34 %. In copper metal. The eight roller pressed the surface of the work piece more deeply and

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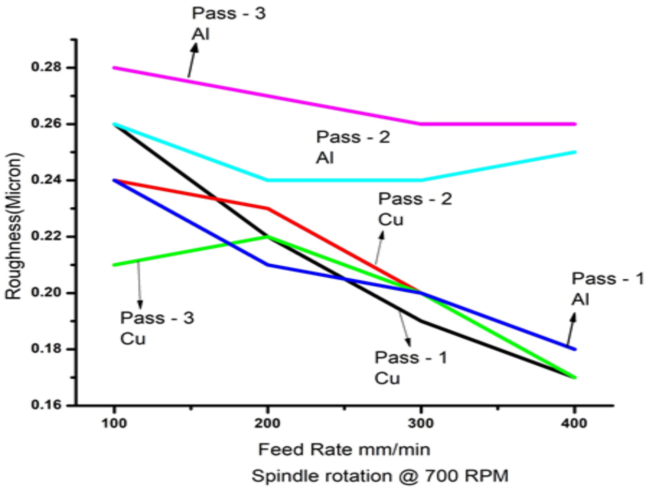
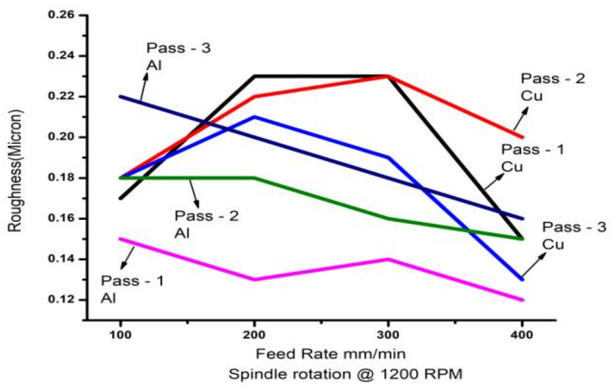
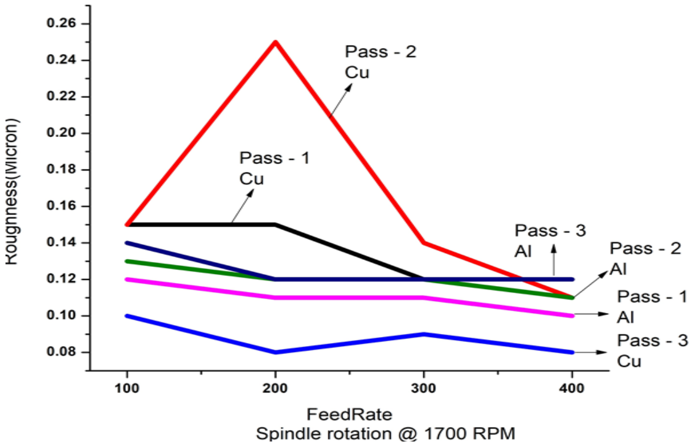
plastic deformation was spread over the surface and much smother roughness obtained in terms of value. Aluminum is a soft metal compared to copper. In comparison, as the spindle rotation increased from 700 to 1200, to 1700 and 2200 RPM for the same feed rates of 100, 200, 300 and 400 mm / rev the surface roughness value was much lower 700 RPM. However, the reduction in percentage is lower than 700 RPM rotational speeds. In each pass at different spindle rotation, there was much reduction surface roughness and smooth finish was obtained.



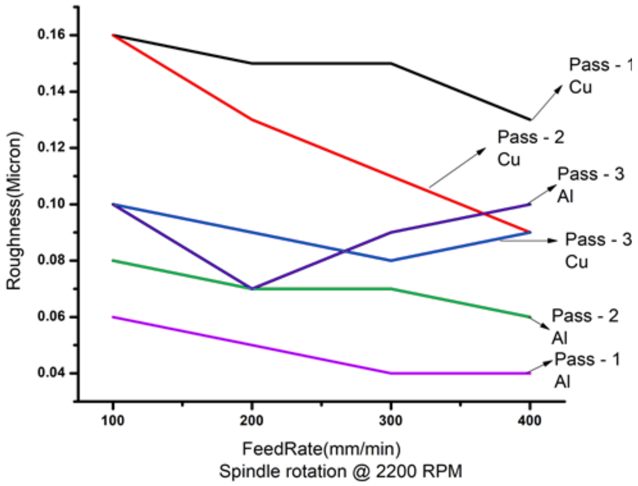
(a). Spindle RPM 700 Vs Surface Roughness



(b). Spindle RPM 1200 Vs Surface roughness



(c). Spindle RPM 1700 Vs Surface roughness



d). Spindle RPM 2200 Vs Surface Roughness

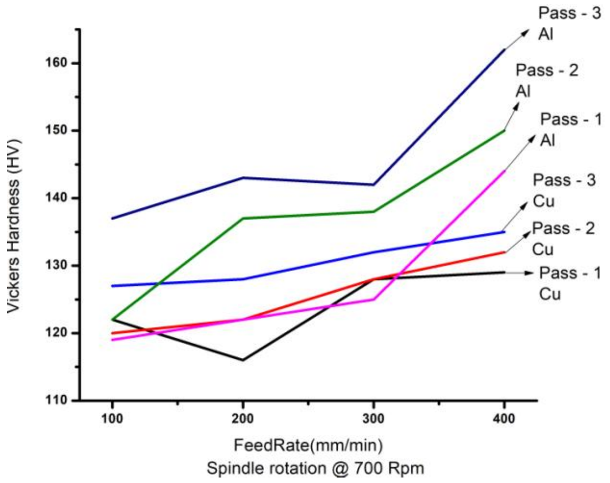
Fig.3. (a) to (d) shows spindle rotation Vs roughness at various feed rates (F.R.)

While, burnishing aluminum metal, the following observations were recorded and presented in the graphical form. The surface roughness as machined was 474 microns and more rough than copper. In pass 1 at spindle rotation of 700 RPM at feed rate of 100 mm / rev. the roughness value was 0.24 microns and reduced to 0.18 microns at feed rate of 400 mm / rev. in pass 1. At the end of pass 2 the roughness value was 0.25 micron and pass 3, the value was 0.25 microns. There was considerable reduction in each pass at spindle rotation of 700 RPM. As the spindle rotation is varied from 700 to 1200, 1700 and 2200 RPM in all the four feed rates, there was much reduction in smoothness on the surface which is clearly shown by graphical representation. At high spindle rotation of 2200 RPM much lower or brighter finish was noticed like mirror finish.

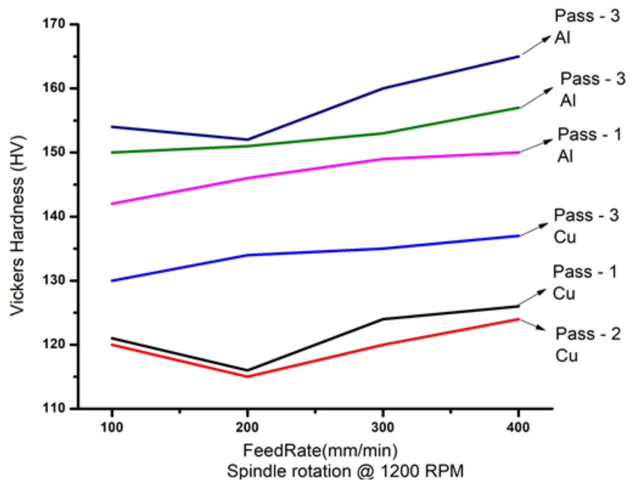
B. Surface hardness

The surface hardness in a component is another important parameter for engineers for performance. The burnishing process can increase the surface hardness. Hpngyum et al. [16] studied the effect of burnishing parameters on surface micro-hardness by burnishing with cylindrical PCD tools which was effectively to improve surface hardness. The surface hardness produced by this application eliminates the heat treatment where lower hardness is required. Fig.4 (a) to (d) show the surface hardness produced at various feed rates. Initial surface hardness as machined was 107 HV and 107 HV in copper and aluminum material respectively. At 700 spindle rotation, at feed rates of 100, 200, 300 and 400 mm/rev. surface hardness obtained was 122 BHN in pass 1 and increased to 129 BHN at end of 400 mm / min. feed rate. There was gradual increase in the surface hardness from 119 BHN to 144 BHN at the end pass 1. There was increase in hardness from 122 BHN to 132in pass 2, 127 BHN to 135 BHN at the end of pass 3 starting at feed rates 100 to 400 mm / min. for copper metal. It is shown in the figure 4 (a) both for copper and aluminum. Similarly, there was increase in surface hardness ranging from 119 BHN to

144 at feed rate 100 mm / min feed rate to 400 mm/min. feed rate. In pass 2, surface hardness increased from 122 BHN to 150 and 137 BHN to 162 BHN for the respective feed rates. It is known from the graphs 4 (a) to (d) for various feed rates from 100,200, 300 and 400 mm /min. there was definite increase from surface hardness and increased from minimum of 8% to maximum of 12 %. In burnishing copper metal. In case of aluminum metal, the surface hardness increased from minimum of 119 BHN to 144 BHN an increase of 17 % maximum at high feed rate of 400 mm /min.

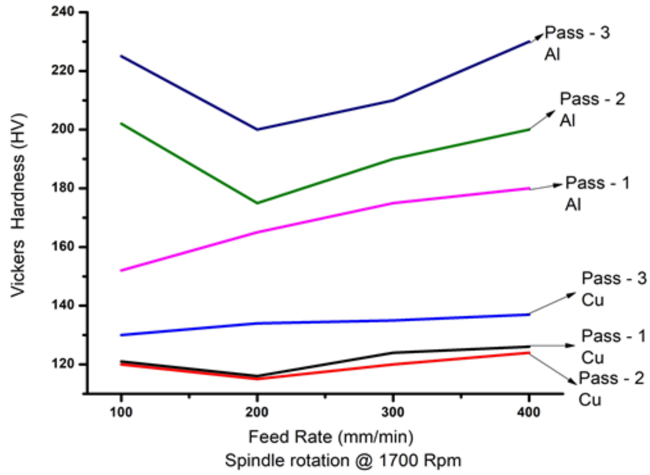


(a). Spindle RPM 700 Vs Surface Hardness

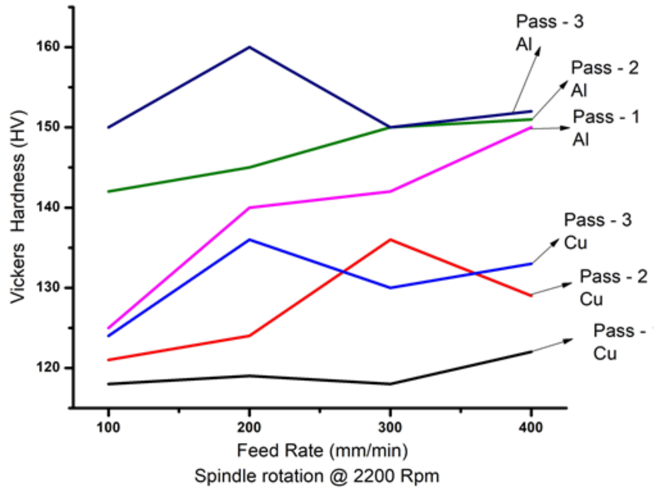


(b).Spindle RPM 1200 Vs Surface Hardness

In all spindle rotation in burnishing aluminum metal, there was definite increase in the surface hardness. It is depicted in the figures 4 (a) to (d). All the feed rates used in this experiment has increased the surface hardness ranging from minimum of 1116 BHN to maximum of 133 BHN in burnishing copper and in burnishing aluminum it is increased from minimum of 119 BHN to 230 BHN maximum. However, at various feed rates the results has been obtained and feed rate has impact on surface hardness by cold working process.



(c). Spindle 1700 rpm Vs surface hardness



(d). Spindle 2200 rpm Vs surface hardness

Fig.4. (a) to (d) shows spindle rotation Vs surface hardness at various feed rates (F.R.).

This increase can be attributed to:
(i) the reduction in surface roughness due to the burnishing action; (ii) the elimination of flaws on the surface, as the burnishing action causes the metal to flow plastically, filling existing voids or defects; and (iii) the setting of compressive stresses in the outer circumferential area of the specimens. The effect can be studied by conducting the fatigue life of the burnished specimen. However, it was not in the scope of the study except the study on surface roughness and surface hardness. However, further work in this direction fatigue life will be required to confirm this possibility.

Fig. 5 (a) and (b) show the cut section of the surface hardness obtained and plastic deformation caused by burnishing. The similar process occurred in all the experiments and white band surface is the level hardness obtained.

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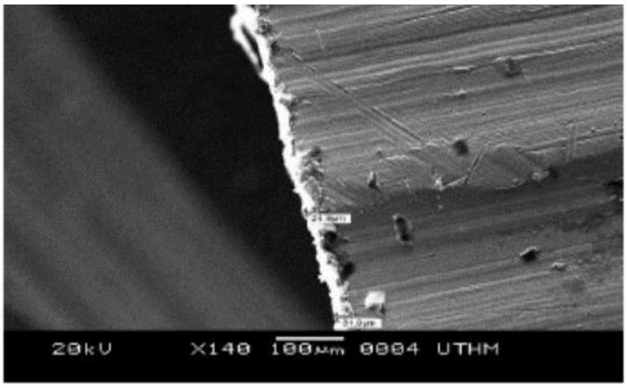
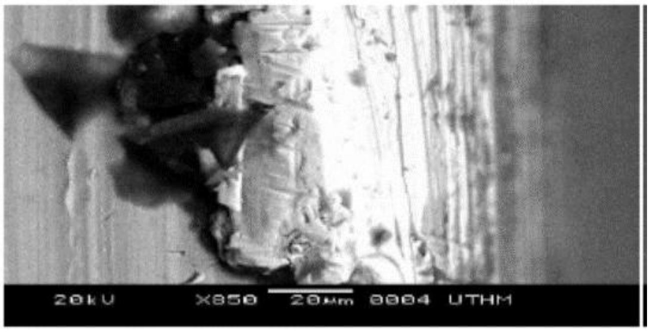


(a). SEM view on surface hardness



(b).SEM view on plastic deformation

Fig.5. (a) and (b) SEM views on surface hardness and plastic deformation respectively.

V.CONCLUSION

The following are the important conclusions that can be drawn from the present work:

01. An improvement in surface finish and an increase in surface hardness can be achieved by subjecting the Surface of metallic specimens to the ball-burnishing process.
02. An increase in initial surface roughness will cause an increase in the final surface roughness of the ball burnished components. An increase in the initial surface hardness will cause a decrease in the reduction of surface roughness, and in the total amount of the increase in surface hardness.
03. There was definite effect by feed rate in improving the surface roughness and surface hardness. There were variations in all the values.
04. A further research in increase depth of penetration from 0.50 mm, 0.75 and 1.00 is necessary to understand more on the effect by feed rates.
05. The working parameters of the ball-burnishing process should be kept under close control, otherwise.
06. The burnishing process can produce surface hardness which will suit for shafts needed hardness for lighter application.

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