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Effect of Roller Burnishing on the Mechanical Behavior and Surface Quality of O_1 Alloy Steel

Khalid. S. Rababa and Mayas Mohammad Al-mahasne
Department of Mechanical Engineering, Tafila Technical University,
P.O. Box 179, 66110 Tafila, Jordan

Abstract: The main aim of this study is to enhance the mechanical properties and microhardness of the surface of O_1 steel using the roller burnishing process. In manufacturing processes, surfaces and their properties are as important as the bulk properties of the materials. Surface treatment is an important aspect of all manufacturing processes. It has been used to impart certain physical and mechanical properties, such as appearance, corrosion, friction, wear and fatigue resistance. Widely used methods of finishing treatment that create necessary parts with the given roughness usually do not provide optimum quality of the surface. Therefore, methods of Surface Plastic Deformation (SPD) are used. One of the most effective representatives is the roller burnishing. This can simply achieved by pressing a hard and highly polished ball or roller against the surface of metallic work pieces. In this paper the effect of diamond pressing process with a different pressing force (105, 140, 175, 210) N was studied and the results of the experiments are presented. The major findings of this study are; the true stress of material has been increased of about 150 MPa, the surface quality has been enhanced by 12.5%, finally the U.T.S. has been increased by 166 MPa.

Key words: Mechanical behavior, microhardness, O_1 alloy steel, roller burnishing, surface quality

INTRODUCTION

Surface treatment is an important aspect of all manufacturing processes. It has been used to impart certain physical and mechanical properties, such as appearance, corrosion, friction, wear and fatigue resistance. Ruler burnishing, a plastic deformation processes, is becoming more popular in satisfying the increasing demand of machine component performance and reliability (El-Tayeb *et al*., 2006; Loh *et al*.,1989a). Thus investigating the parameters of these processes to improve the product quality is especially crucial. The objective of this paper is to evaluate the effect of different conditions on surface hardness and roughness. Ruller burnishing is considered as one the surface plastic deformation methods (shot peening , roller burnishing) and it is one of the effective fishing treatment methods in terms of stabilization of surface layers properties along the depth, a field of which application is yet narrow . RB is a finishing treatment method that is used to impart certain physical and mechanical properties, such as surface roughness improved visual appearance, and increased corrosion, friction, wear, and fatigue resistance. The RB process is a method of working a metal surface to improve its finish and dimensional accuracy and can provide some degree of work hardening. This is a cold-working process that uses a smooth hard roller with a sufficient pressure to rub on the metal surface and does not involve metal removal. A comprehensive classification of burnishing tools and their application has been given by (Shneider, 1969). A literature survey shows that work on the burnishing process has been conducted by many researchers and the process also improves the properties of the parts, for instance: increased hardness (Hassan and Al-Bsharat,1996; El-Axir, 2000; Loh *et al*., 1989b; Fattouh *et al*., 1988), surface quality (Lee *et al*.,1992; Hassan and Al-Bsharat, 1996; Lee *et al*., 1992, 1993), increased maximum residual stress in compression (Hassan and Al-Bsharat, 1996; Fattouh and El-Khabeery, 1989), and higher wear resistance (Hassan and Sulieman, 1999; Niberg, 1987; Michael *et al*., 1989). The parameters affecting the surface finish are: burnishing force, feed rate, ball material, number of passes, workpiece material, and lubrication. RB is applicable to the finishing of tapered holes, inside and outside cylindrical surfaces, and continuously curved surfaces. However, metals that work harden rapidly must be at lower hardness (less than 40 Rockwell Hardness Scale C) before RB and surface hardness increases to depth of 0.13-0.76 mm (Davies *et al*., 1999). RB is used to improve the mechanical properties of the surface layer, as well as the shape and surface finish of the component. It can be used separately or in combination with other finishing

Corresponding Author: Khalid. S. Rababa, Department of Mechanical Engineering, Tafila Technical University, P.O. Box 179, 66110 Tafila, Jordan

Table 1: Chemical composition of O_1 alloy steel

Type:(AISI)	Cwt =%	Siwt %	Mnwt %	Crwt %	Mowt %
O_1	0.95	-	1.1	0.6	-

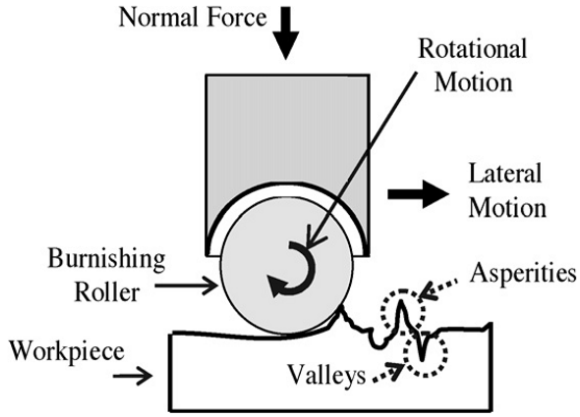

Fig. 1: Schematic illustration of burnishing mechanism (El-Tayeb *et al*., 2006)

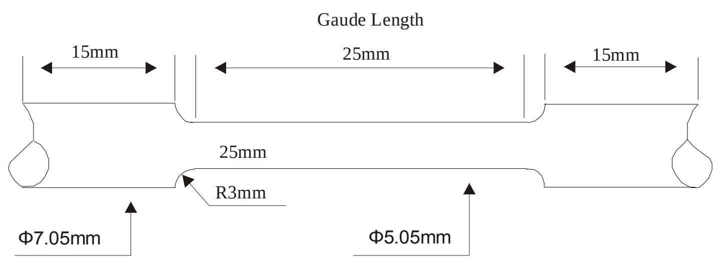

Fig. 2: The standard tensile specimens test (S….)

processes such as grinding, honing, and Lapping (Schey, 2000). The mechanism of burnishing process is shown in Fig. 1.

The main objective of this study focused to investigate the cold work process (roller burnishing) on the mechanical properties and surface quality of O_1 allot steel.

Materials, equipment and experimental procedure: The study was conducted at the mechanical engineering laboratories in Tafila technical university within 2010 study year. In this study $_{O1}$ alloy steel has been studied, ARNE general purpose oil-hardening tool steel is a versatile manganese-chromium-tungsten steel suitable for a wide variety of cold-work applications. It has good machinability, Good dimensional stability in hardening, and a good combination of high surface hardness and toughness after hardening and tempering. These characteristics combined to give a steel suitable for the manufacture of tooling with good tool-life and production economy. ARNE can be supplied in various finishes including hot-rolled, pre-machined and precision ground. The chemical composition of O_1 steel is shown in Table 1.

Tensile test: Tension test is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on the material, As the material is being pulled, you will find its strength along with how much it will elongate. A curve will result showing how it reacted to the forces being applied. The point of failure is of much interest and is typically called UTS on the chart. The test was carried out on work piece at strain rate 1×10^{-3}, the load-deflection curve was obtained from which the true stress-strain diagram is graphical for each alloy steel. The dimension is shown in Fig. 2.

The instron machine and the work specimens after fracture are shown in Fig. 3.

Burnishing test: The set up of burnishing process is shown in Fig. 4 where the machined specimens were burnished as shown in Fig. 5, The burnishing force were 105, 140, 175 and 210 N. where the feed rate is 0.02 m/s and the rotational speed 100 rpm. The numbers of passes are three.

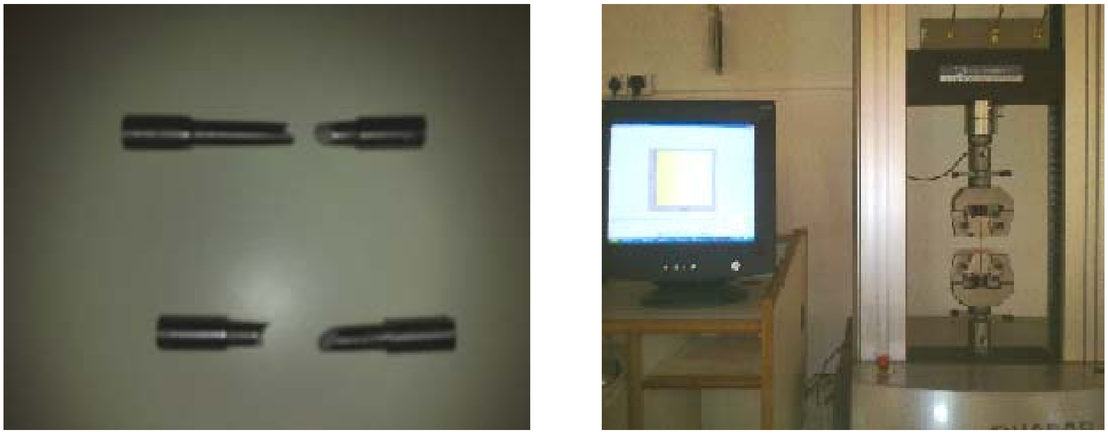

Fig. 3: a) The specimens after fracture, b) the instron tensile machine

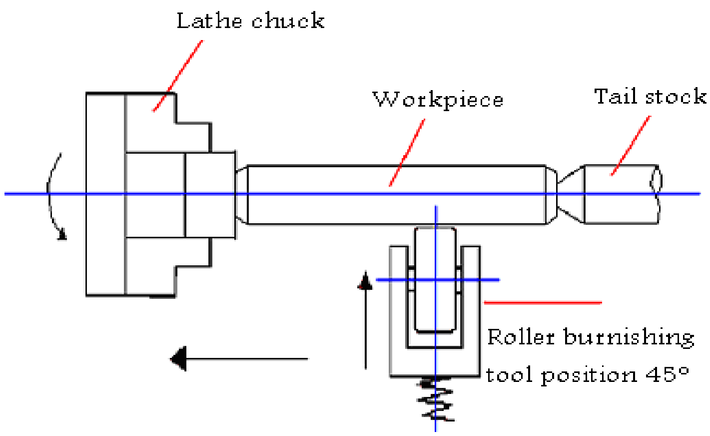

Fig. 4: Detailed sectional view of roller burnishing tool assembly (Al-Qawabah *et al.*, 2010)

Fig. 5: a) Burnishing tool b) Lathe and burnishing tool

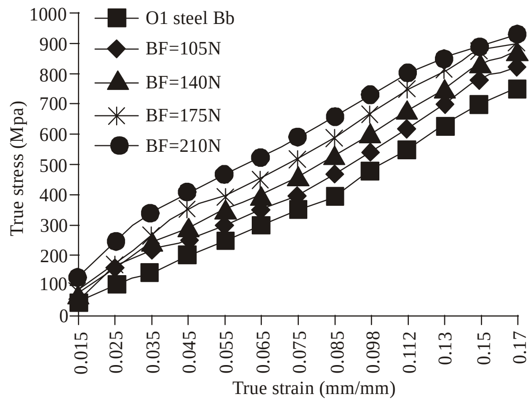

Fig. 6: True stress strain diagram for O_1 alloy steel under different burnishing forces

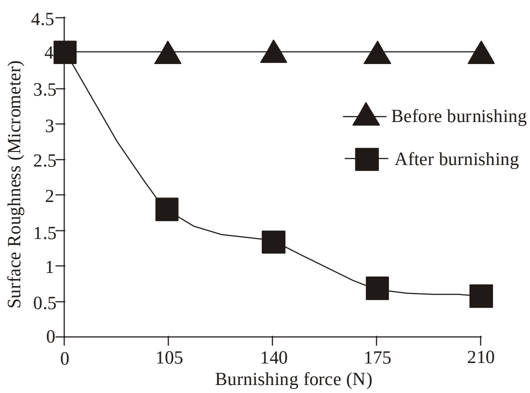

Fig. 7: The effect of burnishing forces on surface roughness of O_1 alloy steels

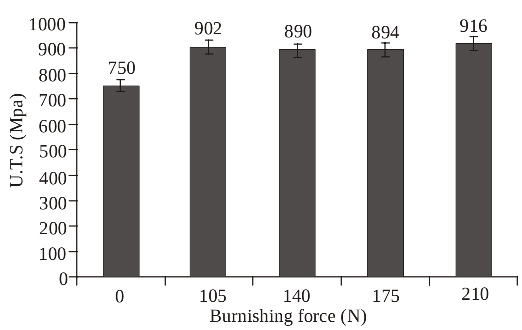

Fig. 8: The effect of burnishing forces on the ultimate tensile strength of O_1 Alloy steel

RESULTS AND DISCUSSION

Effect of roller burnishing on the mechanical characteristics of O_1 tool steel: Figure 6 shows a comparison between the true stresses of O_1 specimen under different burnishing forces the figure shows that the specimen which subjected to burnishing force of 210 N

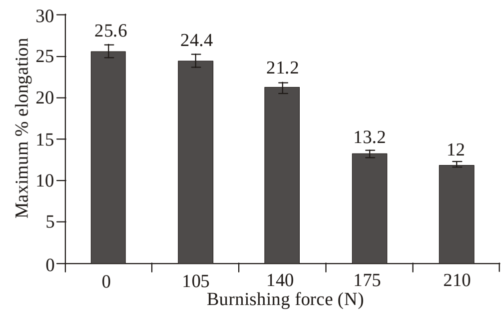

Fig. 9: The relation between BF and ductility of O_1 alloy steel

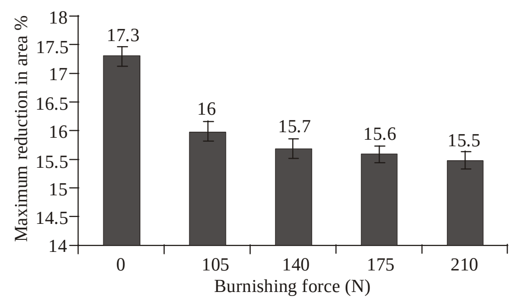

Fig. 10: The relation between the burnishing force and the percentage reduction in area

has a better stress state until reached the point where the ultimate stress which shows that all specimens having approximately the same values of ultimate stress. The fig shows also that the burnishing forces of F = 140 N and F = 175 N have the same effect. The burnishing force of F = 105 N has no burnishing effect at a moderate values of strains = 0.12 but it has an effect at higher values of strain

Effect of roller burnishing on the surface texture of O_1 tool steel: It can be seen from Fig. 7 that by increasing the BF, average roughness will decreased of about (55,62.5%) at BF of (105,140 N), respectively, and the maximum effect of about (135,150%) at (175,210 N), respectively, The values of surface roughness is shown in Appendix A, using surface roughness tester (Kosaka Surfcorder SE 3500).

Effect of roller burnishing on the U.T.S of O_1 tool steel: It can be seen from Fig. 8 that by increasing the BF, UTS will increased until burnishing force reaches (105 N). At (105 to 175 N) the BF has approximately the same effect, continuing increasing of BF the UTS will again increased until it reaches (916 MPa) at (210 N) of BF, but approximately all the BF resulted of about (22.1%) .

Effect of roller burnishing on the maximum % elongation of O_1 tool steel: It can be seen from Fig. 9 that

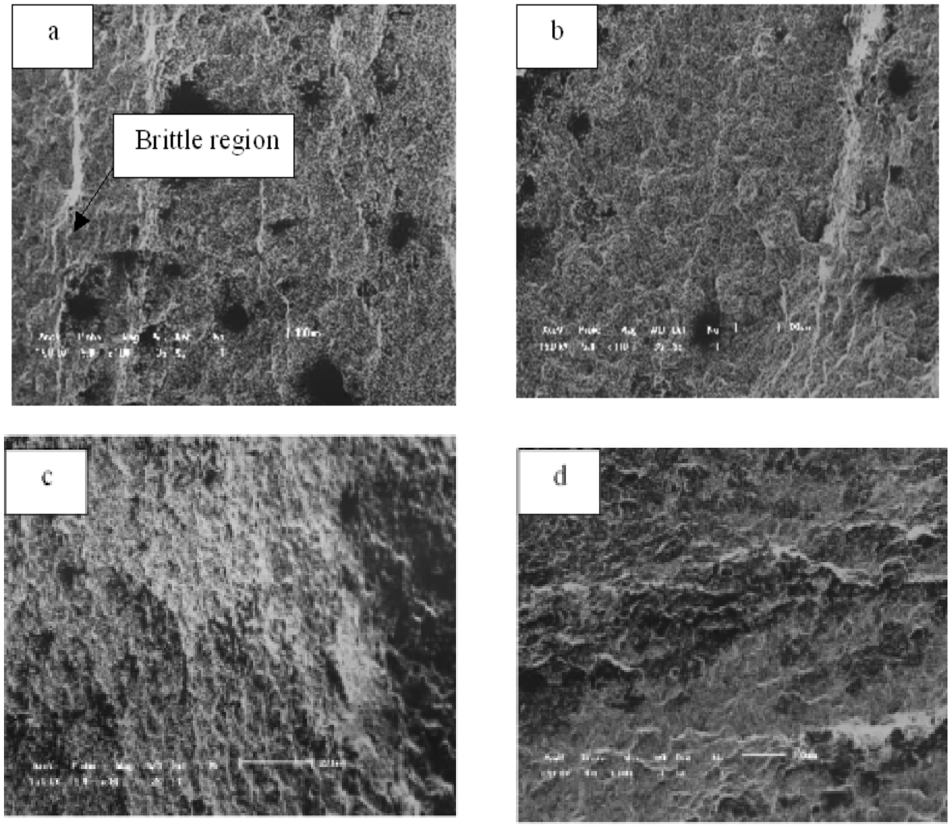

Fig. 11: SEM of O_1 alloy steel at 100x (a) F = 105 N, (b) F = 140 N, (c) F = 175 N, (d) F = 210 N

there was a slight increase at (F = 105 N) but there was a (76.6, 103.3, 113.3%) increasing at BF (140, 175, 210), respectively.

Effect of roller burnishing on the maximum reduction of area % of O_1 tool steel: It can be seen from Fig. 10 that there is a slightly increase in reduction in area percentage from (F = 105 to F = 175 N) but there is an 11.6% enhancement in the reduction in area percentage at (F = 210 N). This can be attributed to the plastic deformation (cold work) performed on the surface.

Effect of roller burnishing on the fracture surface of O_1 alloy steel: It can be seen from Fig. 11a that the fracture surface has a brittle fracture regions (shine region) where the dark one are represent ductile fracture, it can be seen also that the shine areas are distributed in all fracture surface area. However it can be seen from Fig. 11b that the brittle was localized in certain region. On the other hand it was obvious from Fig. 11d that the type of fracture was completely ductile. Furthermore it can be seen from Fig. 11c that the brittle region was localized in certain region.

CONCLUSION

The following can be concluded:

- RB process has a large effect on the micro hardness of O_1 alloy steel
- The stress of material has been increased of about 150 MPa
- RB has a positive effect on the surface roughness of O_1 alloy steel. The improvement percentage on the surface quality was 12.5%
- RB has an effect on the ultimate tensile strength, the UTS has been increased by 166 MPa
- RB has an effect on ductility of material; the percentage elongation of material has been increased of 13.6%
- RB has an effect on cross sectional area, the reduction of cross sectional area has been increased of 1.8 %

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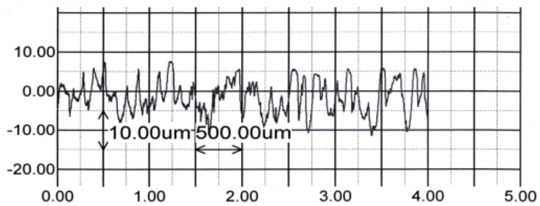
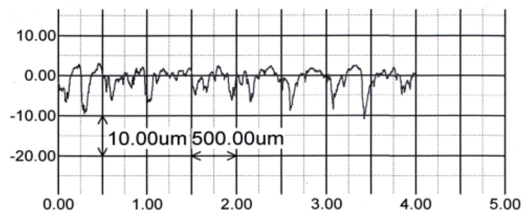
Appendix A:
Figure 1 shows the effect of different pressing forces of RB process on the mean roughness



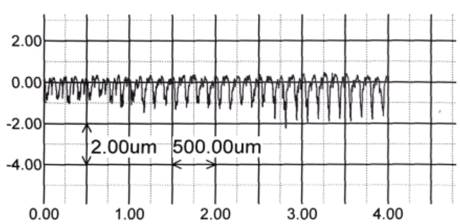
M.PartName		
Comment		
Cutoff	Lc0.8mm	
Standards	ISO 13565(R	
V.Mag	x2,000	
Filter	SpGauss	
M.Speed	0.5mm/s	
E.length	4.000mm	
S.length	0.800mm	
Levelling	none	
JIS'82		
Ra (um)	3.53	
Rq (um)	4.31	
Rmax (um)	142.57	
Rz (um)	28.51	

(a)



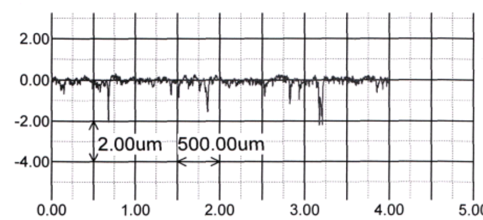
M.PartName		
Comment		
Cutoff	Lc0.8mm	
Standards	ISO 13565(R	
V.Mag	x2,000	
Filter	SpGauss	
M.Speed	0.5mm/s	
E.length	4.000mm	
S.length	0.800mm	
Levelling	none	
JIS'82		
Ra (um)	1.87	
Rq (um)	2.47	
Rmax (um)	139.35	
Rz (um)	27.87	

(b)



M.PartName	
Comment	
Cutoff	Lc0.8mm
Standards	ISO 13565(R
V.Mag	x2,000
Filter	SpGauss
M.Speed	0.5mm/s
E.length	4.000mm
S.length	0.800mm
Levelling	none
JIS'82	
Ra (um)	0.40
Rq (um)	0.49
Rmax (um)	2.98
Rz (um)	2.75

(c)



M.PartName	
Comment	
Cutoff	Lc0.8mm
Standards	ISO 13565(R
V.Mag	x2,000
Filter	SpGauss
M.Speed	0.5mm/s
E.length	4.000mm
S.length	0.800mm
Levelling	none
JIS'82	
Ra (um)	0.18
Rq (um)	0.32
Rmax (um)	4.53

(d)

Fig. 1A: Surface roughness of O_1 alloy steel spacemen with burnishing forces of: (a) F = 105 N, (b) F = 140 N, (c) F = 175 N, (d) F = 210 N

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