# SOME SURFACE CHARACTERISTICS DUE TO CENTER REST BALL BURNISHING

# بعض خصائص السطح الناتج بعملية الصقل بالضغط باستخدام المخنقة

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## الخلاصة

تعتبر المخرطة احدى الماكينات الهامة التى تستخدم فى انتاج معظم الأجزاء الميكانيكية. بعض هذه الأجزاء يجب أن تشطب بدقة عالية والتى لايمكن الحصول عليها بعملية الخراطة وحدها.

لذلك يهدف هذا البحث الى استخدام احدى ملحقات المخرطة وهى المخنقة المتحركة كأداة للصقل بالضغط لتشطيب السطح المشغل حيث تم اجراء تعديلات بالمخنقة وتم تثبيتها مع عربة المخرطة لتتحرك معها بمقدار التغذية المحدد وتم استبدال الثلاث لقم الموجودين بها بأدوات صقل من النوع الكروى.

وقد أجريت التجارب على المخرطة لدراسة تأثير متغيرات عمية الصقل باستخدام هذه الأداة الجديدة على خصائص السطح الناتج وهذه المتغيرات هى: سرعة الصقل، قوة الصقل، ومعدل تغذية الصقل. وخصائص السطح الناتج التى تم قياسها هى: خشونة السطح، الاستدارة، والتغير فى القطر. وأيضا تم دراسة تأثير عدد أدوات الصقل ( أداة واحدة- اثنتان- ثلاث أدوات) على خصائص السطح الناتج.

وقد أسفرت النتائج عن الحصول على أسطح ذو خصائص جيدة باستخدام هذه الأداة وبتكاليف منخفضة جدا. وأوضحت النتائج أن قوة الصقل ومعدل التغذية من أهم المتغيرات التى تلعب دورا هاما فى التحكم فى جميع خصائص السطح الناتج.

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**ABSTRACT:** Lathe is one of machine tools used to produce round mechanical parts. Most of these parts must be finished with high accuracy which can not be obtained with conducting turning process only. Therefore, the objective of this work is how the center rest can be used to finish the round machined parts in suite on the center lathe. To achieve the object, three ball burnishing tool are designed and constructed as long as replacing the three original adjustable jaws of the moving rest.

Experimental work was carried out on a lathe to study the effect of this new burnishing tool and the lathe parameters; such as, burnishing speed, burnishing force, and burnishing feed on some surface characteristics which are; surface roughness, surface roundness and reduction of diameter.

The results showed that good surface characteristics can be obtained by using this new burnishing tool with minimum cost as a result of transfer the center rest from only support element to super finish tool (burnishing tool). Burnishing force and burnishing feed are the most important parameters that play an important role in controlling the values of all surface characteristics investigated in this work.

**KEYWORDS:** Burnishing, center rest, surface roughness, surface roundness, change in diameter

## 1. INTRODUCTION

During recent years, considerable attention is being paid to the post-machining metal finishing operations such as burnishing which improves the surface characteristics by plastic deformation of the surface layers [1]. Burnishing is essential by a cold-forming process, in which the metal near a machined surface is displaced from protrusion to fill the depressions. Besides producing a good surface finish, the burnishing process has additional advantages over other machining processes, such as increased hardness, corrosion resistance and fatigue life as result of the producing compressive residual stress.

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 [2-7], surface quality [2,7-9], increased maximum residual stress in compression [2,10,11], higher wear resistance [12-14] and decreased out of roundness [15]. The parameters affecting the surface finish are: burnishing force, feed, ball or roller material, number of passes, workpiece material, and lubrication [2].

The present paper examines the use of a new ball burnishing tool ( moving rest burnishing tool) to give good surface characteristic such as, higher surface finish, less out of roundness and the smaller change of workpiece diameter that play an important role on the required tolerance and fit especially during assembly of parts. The effects of three burnishing parameters; namely; burnishing speed, feed, and burnishing force on three different responses, which are, the surface roughness, out-of-roundness and change in the workpiece diameter are comprehensively studied through this work .

## 2- EXPERIMENTAL WORK

### 2-1. WORKPIECE MATERIAL

In this work, mild steel was used as a workpiece material. The chemical composition and mechanical properties of the material are as follows:

| %C | %S | %Mn | %P | %S | $\sigma_U$ (N/cm²) | $\sigma_Y$ (N/cm²) | B.H.N |
|---|---|---|---|---|---|---|---|
| 0.25 | 0.25 | 0.55 | 0.045 | 0.045 | 450 | 230 | 130 |

This material was selected because of its importance in industry and its susceptibility to degradation when burnished, through surface and subsurface damage.

**2-2.WORKPIECE PREPARATION**

The material was received in the form of solid bars that was machined into workpieces having the dimensions shown in Fig. 1. The workpieces were prepared with three recesses such that each specimen could be used in three different conditions at positions to study the effect of the number of balls which were used during burnishing using the center rest burnishing tool; one ball (part A) , two balls (part B), three balls (part C) further more a portion D was left without burnishing for comparison purposes with portions A, B and C. The part E which is shown in the figure is safety length to avoid the impact of the rest with the chuck

Fig. 2a shows a specimen attached to the chuck and the center rest burnishing tool which constructed to achievement the aim of this work. While fig. 2b shows one tool of three ball

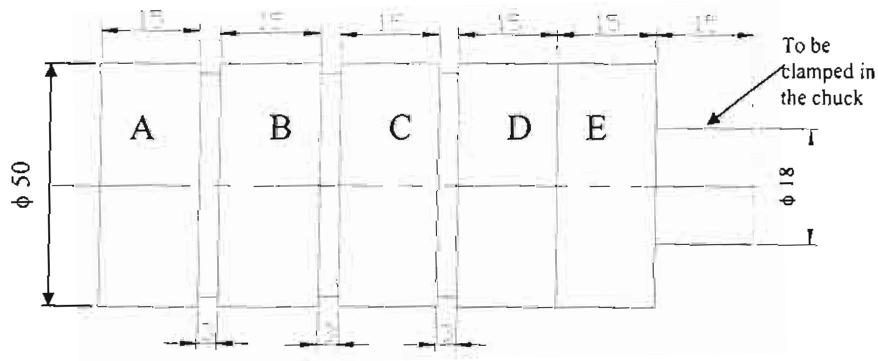
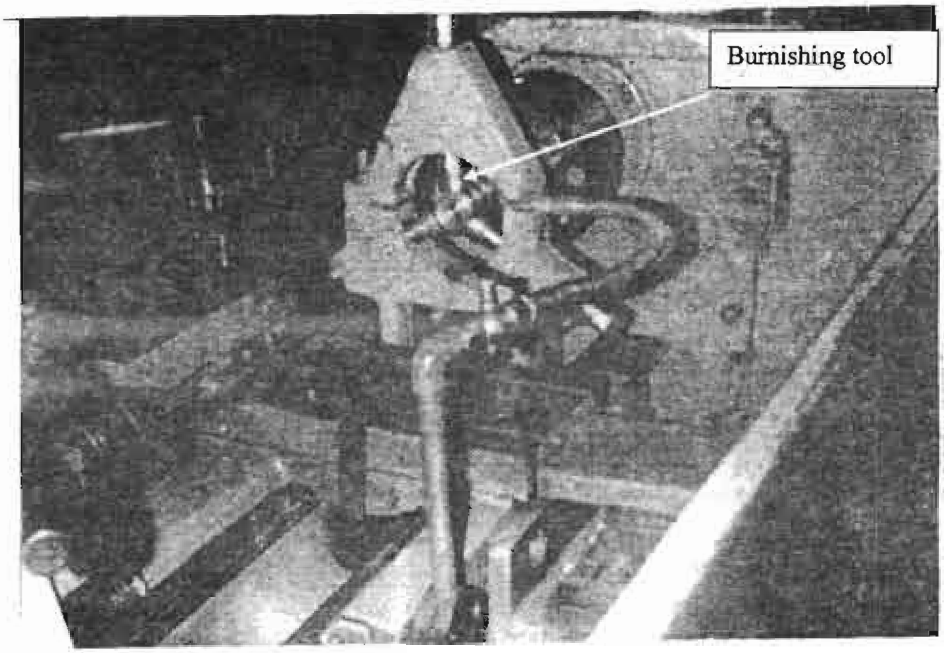
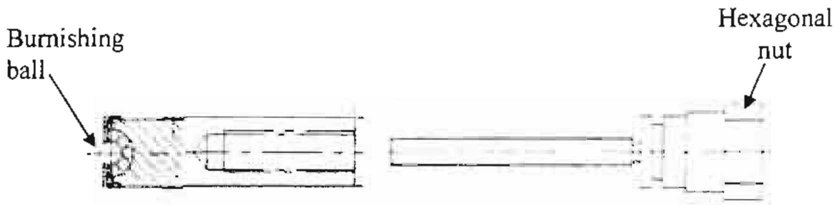



Fig. 1 Workpiece geometry, Dimensions in mm

burnishing tools which are designed and constructed to replace the three original adjustable jaws of the steady rest.




(a) A specimen attached to the chuck and center rest burnishing tool




(b) Burnishing tool

Fig. 2 Burnishing tool and its attachment to the center rest

As shown in the figure each burnishing tool is ended with a hexagonal nut. By tighten this nut with torque arm wrench, variable burnishing forces were obtained. Also burnishing with one, two, and three balls were applied by disable one or two of these tools.

The center rest was clamped with the lathe saddle to move with it as one part and then variable feed rates for burnishing were applied by the lath saddle.

## 2-3. BURNISHING CONDITIONS

In this work, external moving rest ball burnishing tests were performed. All of the burnishing tests were performed under lubricated conditions. The lubrication was performed through the ordinary lathe cooling system.

Only three burnishing parameters were chosen namely, burnishing speed (V), burnishing force (F), and feed (f), also other parameters such as ball diameter and lubrication were held constant throughout the work.

Since dry burnishing conditions produced poor surface finish. It was decided to apply suitable lubricant during all tests which was emulation-type soluble oil mixed with water. Also, constant ball diameters each of 10 mm were used throughout this investigation. The burnishing conditions are summarized in table 1

**Table 1 Summary of Burnishing Conditions Range**

| | |
|---|---|
| Burnishing speed (m/s) | 0.159 -1.84 |
| Burnishing force (N) | 70 - 230 |
| Burnishing feed (mm/rev) | 0.04 - 0.19 |
| Ball diameter (mm) | 10 |
| Burnishing conditions | Lubricated |

## 2-4. MEASUREMENTS

In this work, produced surface roughness, change in workpiece diameter, and out-of-roundness were carefully measured using standard techniques. Different burnishing forces were applied using the torque arm key. Different feeds also were applied using lathe feeds as the center rest was clamped to move with the lathe saddle as one part.

### 2-4-1. Change in the Workpiece Diameter

Ball burnishing process usually reduced the workpiece dimension in the direction (change in diameter). The change in the Workpiece was measured at different places a long and around each test piece using a micrometer with 0.001 mm accuracy.

### 2-4-2. Surface our-of-Roundness

A roundness error is considered as one of the important geometrical errors for cylindrical components because it has negative effects on accuracy and other important factors such as the filling machine elements, and wear in rotating elements. Also, it is well known that only plastic deformation takes place in the surface during the burnishing process, which, in turn, causes variation in the produced roundness. Therefore, surface roundness before and after burnishing was measured using ROUNDTEST RA-112-122. For better results the arithmetic average of three readings has been calculated.

### 2-4-3. Surface Roughness

Quality surface finish affects the functional performance of the surface of the component, wear resistant, load bearing capacity, and corrosion resistance. During burnishing process the tool compress the outer surface layer by the polished hardened tool (ball or roller) so, it reduces the surface roughness. A Talysurf 402 series178 was used for measuring the surface roughness (measured by Ra) after burnishing. It should be pointed out here that the average of three readings for each portion (A,B,C, and D) of the specimens was calculated.

## 3. RESULTS AND DISCUSSION

To study and discuss the effect of the input parameters on the three different responses, Figs. 3-11 are constructed showing the results of the effect of burnishing conditions in the cases of one, two and three ball on the response with the same burnishing conditions on the same figure. It should be pointed out here that in the case of burnishing force, it was found that the results of 70N and 100N and also of 200N and 230N were very close. Therefore, only three levels of burnishing force (70N, 150N and 230N) were presented in each figure.

### 3-1. SURFACE ROUGHNESS

#### 3-1-1. Burnishing Speed

The effect of burnishing speed on the surface roughness in the case of using one, two, and three balls can be assessed from Fig. 3. The results reveal that the effect of burnishing on the surface roughness in the three cases is not the same. In the case of using only one ball, it can be seen that an increase in burnishing speed leads, in general, to a decrease in surface roughness up to about 1 μm/s. The burnished surface roughness starts to increase slightly with any increase in burnishing speeds more than 1 m/sec. This is partly due to the fact that the deforming action of the ball is smaller at high speed and partly due to the chatter that usually induces at high speed.

In the case of applying two balls, there is an interaction between burnishing speed and feed on surface roughness. At low feed, the increment of burnishing speed first decreases the surface roughness reaching to the lower value and then surface roughness starts to increase with further increases in burnishing speeds. At high feed, an increase in burnishing speed leads to a decrease in the burnished surface roughness.

In case of applying three balls, it can be seen for the various feeds, the surface roughness of the burnished surface increases with an increase in burnishing speed. Also, this figure shows that the rang of resulting values of burnished surface roughness is smaller than that in the previous two cases. The deterioration of the surface roughness in the burnishing process at high burnishing speeds is believed to be caused by the chatter that results in instability of the burnishing tool across the workpiece surface.

Fig. 4 shows the effect of burnishing speed on surface roughness at various burnishing forces in the three different cases of the applying balls. The general trend of the results in the three cases reveals there is an interaction between burnishing speed and force. At low burnishing force, the burnished surface roughness decreases with an increase in burnishing speed up to about 1.5 m/s. At high and highest burnishing force, an increase in burnishing speed up to 1 m/s leads to a considerable improvement in surface roughness. This is may be because the lubricant looses its effect due to the insufficient time for it to penetrate between the balls and the workpiece surfaces. It is better then to select low speeds because the deforming action of the burnishing tool is greater and the metal flow is regular at low speed.

In the case of applying three balls, it can be seen that at low burnishing force (70N) the surface roughness of the burnished surface increase with an increase in burnishing speed whereas at forces of 150N and 230N the burnished surface roughness decreases considerably with an increase in burnishing speed. It is believed that when the three balls of the moving rest burnishing tool contact with the workpiece surface the stability of the tool is much more than that at the previous two cases and this leads to a reduction in the effectiveness of chatter.

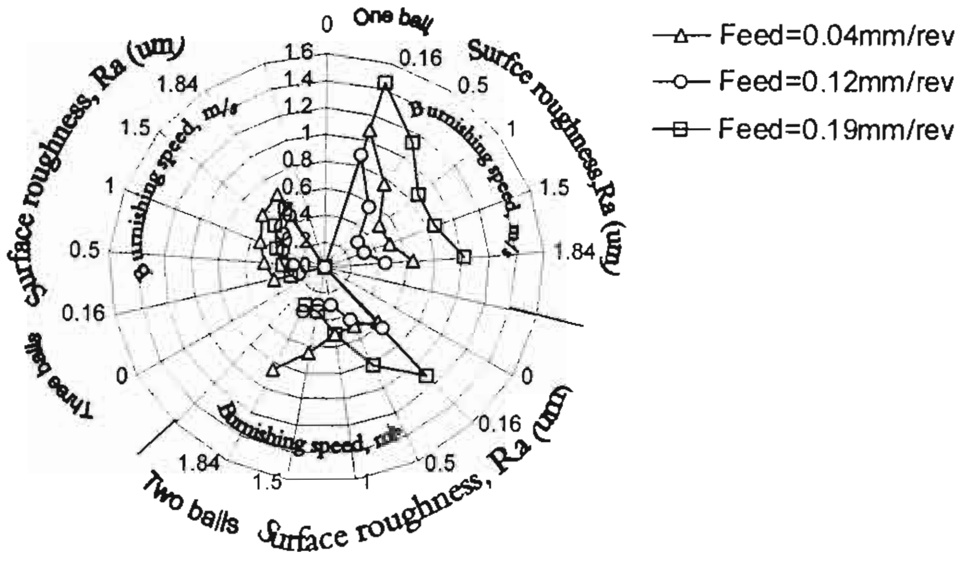



Fig. 3 Effect of burnishing speed on surface roughness at various feeds in case of using one, two and three balls

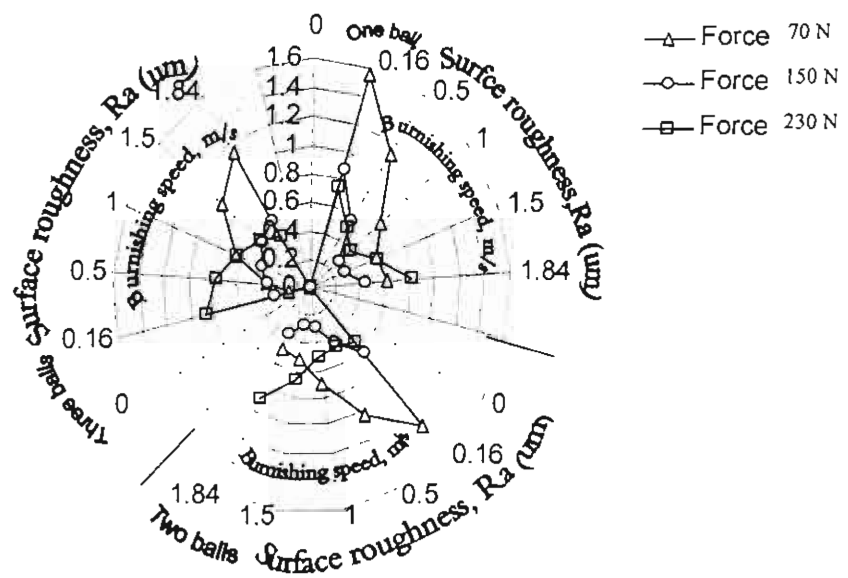



Fig. 4 Effect of burnishing speed on surface roughness at various forces in case of using one, two and three balls

### 3-1-2. Burnishing Feed

The influence of the feed rate on the surface roughness is shown in figs. 3 and 5 for various speeds and forces in the three different cases under the effect of number of balls. The roughness of burnished surface in the three different cases first decreases with an increase in feed reaching to the minimum at about 0.12 mm/rev and then it starts to increase slightly with a further increase in burnishing feed. This may be due to the change of the contact area between the ball and workpiece surface which is dependent on the burnishing parameters especially at very low feed and low forces.

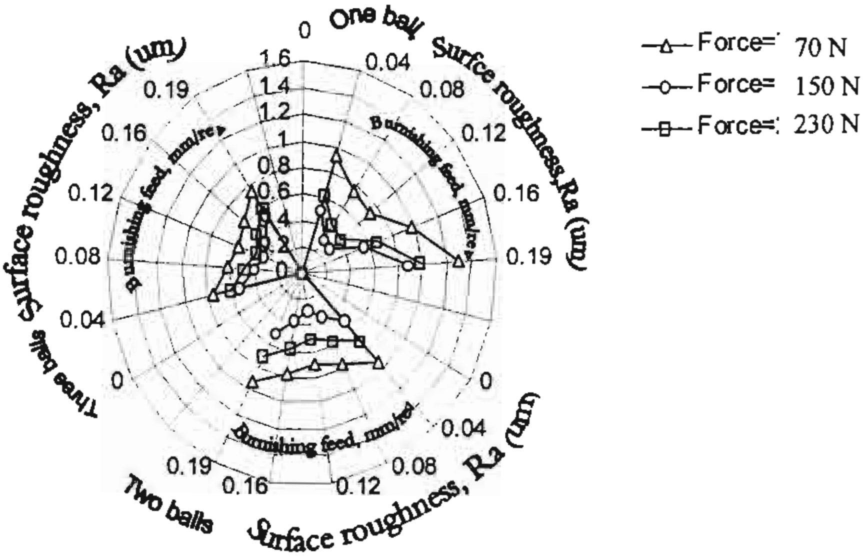



Fig. 5 Effect of burnishing feed on surface roughness at various forces in case of using one, two and three balls

### 3-1-3. Burnishing Force

Figures 4 and 5 show the effect of burnishing force on the surface roughness for different speed and feed, respectively. The best results in the three different cases were obtained at burnishing force of 150 N. Also, from these figures, it can be seen that burnishing force interacts with burnishing speed. At low force an increase in burnishing speed up to 1.5 m/s results in a decrease in surface roughness. At high force the burnished surface roughness increases with an increase in burnishing speed. By increasing the applied force, the bulge in front of the burnisher becomes very large and the region of plastic deformation widens and this damages the already burnished surface or increases the surface roughness.

At high speed, the high surface roughness can be interpreted by the low deforming action of the balls and also because the lubricant loses its effect due to the insufficient time for it to penetrate between the balls and workpiece. It is better then to select low speeds because the deforming action of the burnishing tool is greater and metal flow is regular at low speed.

## 3-2. SURFACE ROUNDNESS

### 3-2-1. Burnishing Speed

The effect of burnishing speed on the variation of out-of-roundness can be assessed from Figs. 6-7. From these figures, it can be seen that in the case of using one ball, as the burnishing speed increases the out-of-roundness decreases at any value of feed and/or force. However in the case of two balls, there is an interaction between burnishing speed and feed. At low feed, an increase in burnishing speed leads to a decrease in the out-of-roundness whereas at highest feed the out-of-roundness increases with an increase in burnishing speed.

The best results can be obtained at a combination of burnishing speed of 1m/s with burnishing feed of 0.12 mm/rev. Also, the obtained results of out-of-roundness applying the moving rest burnishing with three balls are the best.

### 3-2-2. Burnishing Feed

Figs. 6 and 8 present the effect of the burnishing feed on the burnished surface roundness at various speeds and forces, respectively. It can generally be seen that out-of-roundness decreases with an increase in burnishing feed, reaching a minimum value at a burnishing feed of 0.12 mm/rev. A further increase in feed than 0.12 mm/rev causes an slightly increase in surface out-of-roundness. From the results of these two figures that it is preferable, then, to avoid burnishing at very low feeds. This is because may be at very low feed the deforming action of the balls is too high so that the flaking occurs at this very low feed.

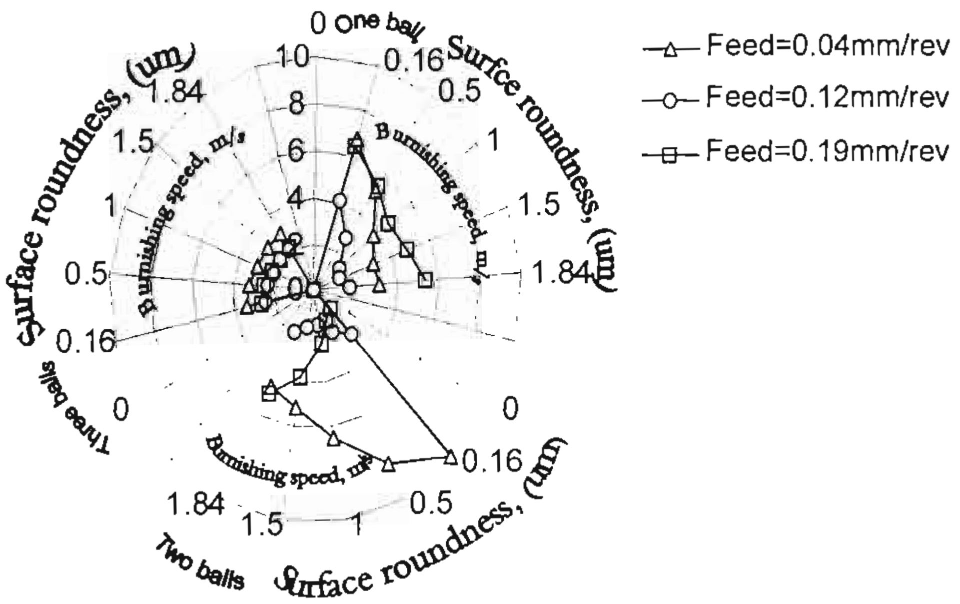



Fig. 6 Effect of burnishing speed on surface roundness at various feeds in case of using one, two and three balls

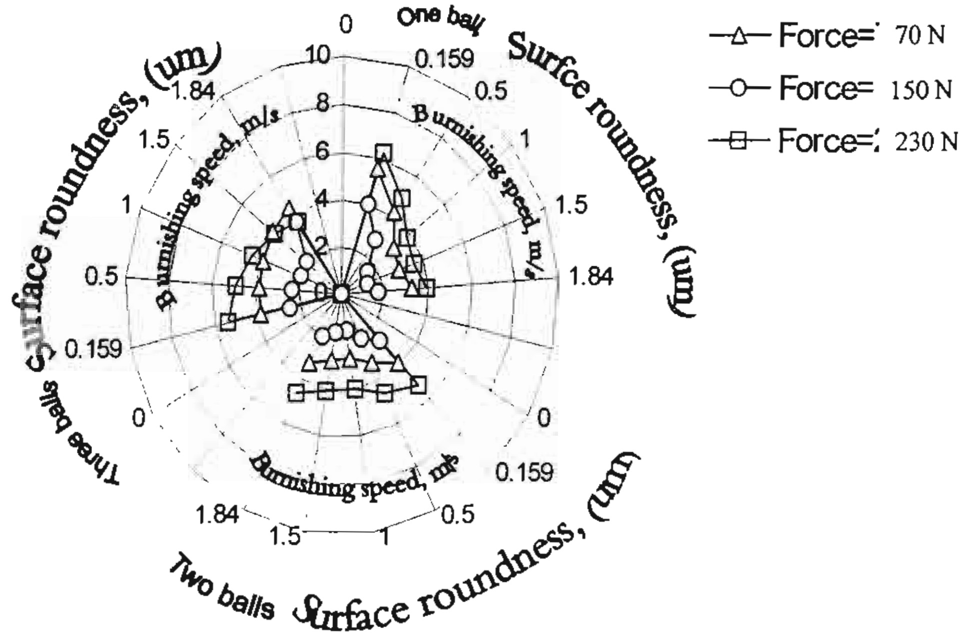



Fig. 7 Effect of burnishing speed on surface roundness at various forces in case of using one, two and three balls

### 3-2-3. Burnishing Force

Burnishing force is one of the very important burnishing parameters that affect the results of this process. The increase in burnishing force causes increase in the amount of surface deformation as the tool passes along the surface of the workpiece. This will lead to an increase in the homogeneity of the surface layers, which have been affected by plastic deformation, so that the out-of-roundness will improve (decrease) via the increase in burnishing force up to 150 N, as shown in Fig. 8. The out-of-roundness of the burnished surface decrease as burnishing force increased as a result of the regularity of the metal flow on the burnished surface from 70 to 150 N. However, the results show that when burnishing mild steel with forces more than 150 N, the surface roundness is deteriorated. This may be because high forces cause shear failure in the subsurface layers which, in turn, results in the flaking.

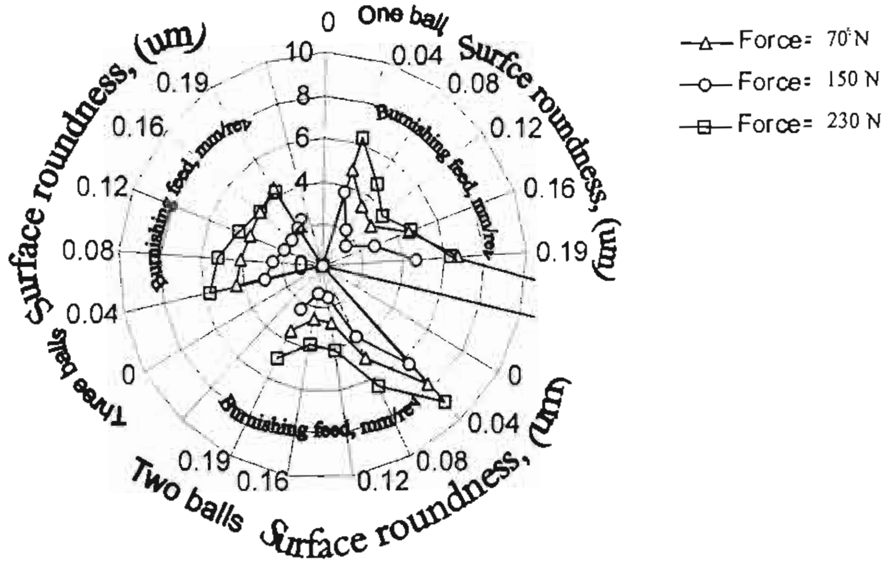



Fig. 8 Effect of burnishing feed on surface roundness at various forces in case of using one, two and three balls

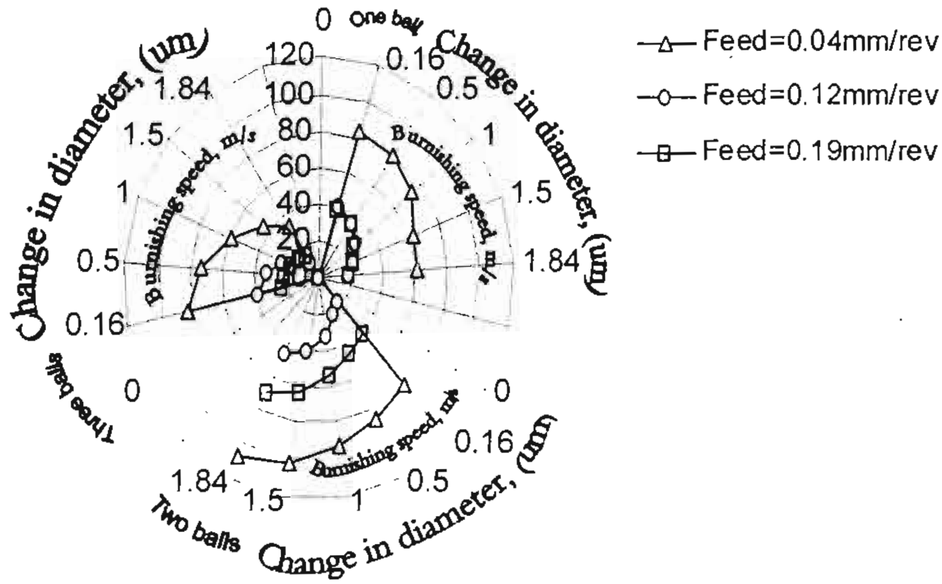



Fig. 9 Effect of burnishing speed on change in workpiece diameter at various feeds in case of using one, two and three balls

## 3-3. CHANG IN WORKPIECE DIAMETER

### 3-3-1. Burnishing Speed

Figs. 9 and 10 present the effect of the burnishing speed on the change in workpiece diameter at various feeds and forces, respectively. From these figures, it can be seen that for the various feed and force used in this work, a change in workpiece diameter decreases with an increase in burnishing speed. It is believed that the increase in the diameter change at low speed is possible due to the high deforming action of the ball of burnishing tool.

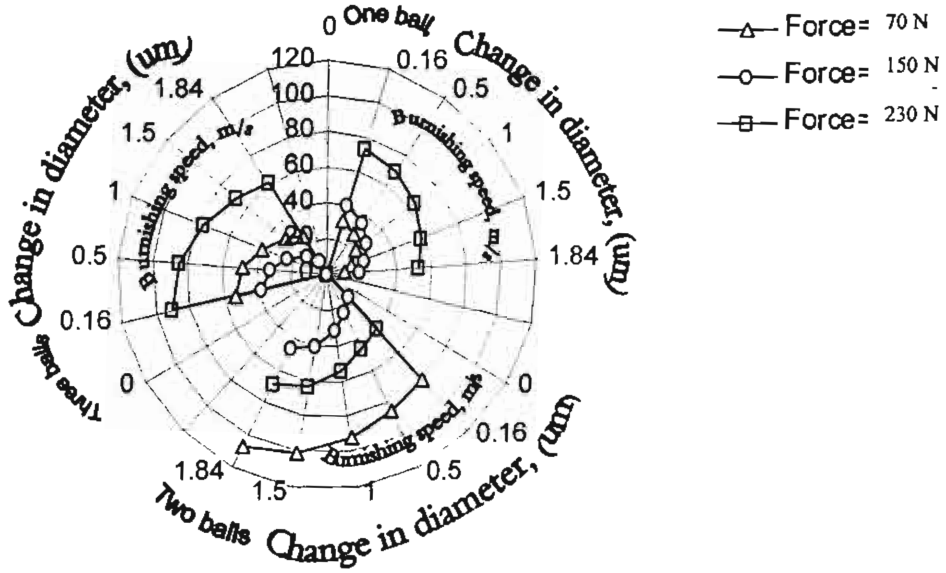



Fig.10 Effect of burnishing speed on change in workpiece diameter at various forces in case of using one, two and three balls

### 3-3-2. Burnishing Feed

Figs. 9 and 11 show the change in diameter versus burnishing feed for different burnishing speeds and force, respectively. The change in diameter considerably with an increase in burnishing feed from 0.04 to 0.12 mm/rev. The maximum change in diameter is obtained at the lo. -st of burnishing feed and burnishing speed used in this work as a result of the significant effect of the ball burnishing tool on the outer burnished surface. The minimum change in the workpiece diameter was obtained in the case of employing the moving rest burnishing tool with the three balls.

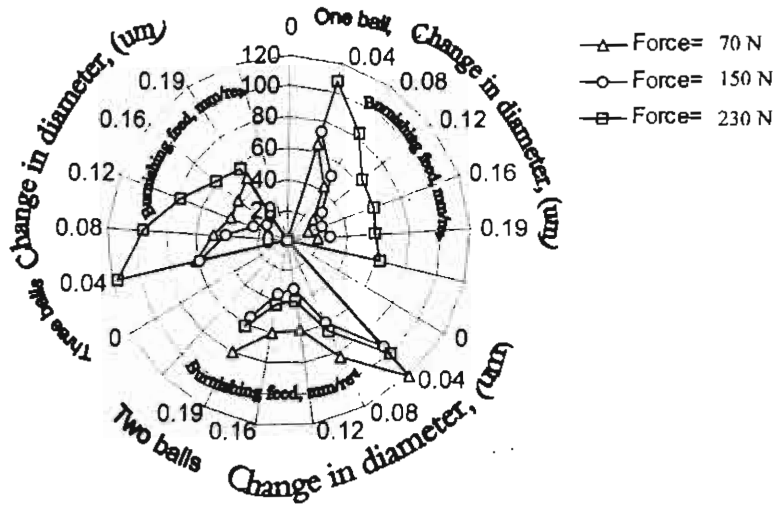



Fig. 11 Effect of burnishing feed on change in workpiece diameter at various forces in case of using one, two and three balls

### 3-3-3. Burnishing Force

Burnishing foree is one of the very important burnishing parameters that affect the results of this moving rest-burnishing tool. It can be seen from Figs. 10 and 11 that, for a given speed and/or feed, an increase in burnishing force causes an increase in change in workpiece diameter of the burnished surface. The increase in the change in diameter when employing high force can be attributed to the increase of the balls pressure on the workpiece surface resulting in compressing most asperities and increase the metal flow which leads to the filling of more voids that exited in the subsurface layer due to machining operation (turning), or as a metal defect.

## 4. CONCLUSION

In this investigation the moving rest was used as a super-finishing tool by replacing the three original adjustable jaws of the moving rest with three ball burnishing tool. The effects of burnishing parameters using this new tool were studied. The following can be concluded from the investigation:

1- The output responses of the burnished surface using the moving rest ball burnishing are mainly influenced by the three parameters used. The burnishing force and burnishing speed play a major role and their effects can be considered as the most important input parameters

2- An increase in burnishing speed up to 1.5 m/s leads to a decrease in both the burnished surface roughness, out-of-roundness and change in workpiece diameter whereas the increase in burnishing speed more than 1.5m/sec result in an increase in both surface roughness and out-of-roundness.

3- An increase in burnishing feed up to 0.12 mm/rev leads to a decrease in all responses studied in this work. The best results for surface roughness and/or roundness obtained at burnishing force of 150 N and burnishing feed 0f 0.12 m/rev.

4- Good results for all responses studied in this work can be obtained using the moving rest burnishing tool applying one ball or three balls.

## REFERENCES

[1] Loh, N. H., Tam, S. C. and S. Miyazawa" A Study of the Effects of Ball-Burnishing Parameters on Surface Roughness Using Factorial Design", Journal of Mechanical Working Technology, 18, P. 53-61, 1989.

[2] El-Axir, M. H., " An Investigation Into Roller Burnishing" International Journal of Machine tool & Manufacturing 40, pp. 1603-1617, 2000.

[3] El-Khabeery, M.M. and El-Axir, M.H. "Experimental techniques for studying the effects of milling roller-burnishing parameters on surface integrity", International Journal of Machine tool & Manufacturing 41, pp. 1705-1719, 2001.

[4] Loh, N. H., Tam, S. C. and Miyazawa S.," Statistical Analyses of the Effects of Ball Burnishing Parameters on Surface Hardness", Wear, 129, pp. 235, 1989.

[5] Yashcheritsyn, I., Pyatosin E.I. and Votchuga, V. V., " Hereditary Influence of Pre-treatment on Roller-Burnishing Surface wear Resistance" Soviet Journal of Friction and Wear, Vol. 8, No.2, pp. 87, 1987.

[6] Fattouh, M., M. H. El-Axir, Serage, S. M.," Investigation into the Burnishing of External Cylindrical Surface of 70/30 Cu-Zn-Alloy", Wear. pp. 127, 1988.

[7] Lee, S.S.G., Tam S.C. , Loh N.H. and Miyazawa, S. "An Investigation into the Ball Burnishing of an AISI 1045 Free-Form Surface", Journal of Materials Processing Technology, 29, pp. 203, 1992.

[8] Lee, S.S.G., Tam S.C. and . Loh, N. H," Ball Burnishing of 316L Stainless Steel", Journal of Materials Processing Technology, 37, pp. 241, 1993.

[9] Hassan, A. M. and Al-Bsharat, A. S., " Influence of Burnishing Process on Surface Roughness, Hardness, and Microstructure of Some Nom-Ferrous Metals" Wear, 199, pp. 1-8, 1996.

[10] Fattouh, M., El-Khabeery, M. M.," Residual Stress Distribution in Burnishing Solution Treated and Aged 7075 Aluminum Alloy", Int. J. Mach. Tools Manufact., Vol. 29, No. 1, pp. 153, 1989.

[11] Klocke, F. and Liermamnn, J. "Roller burnishing of hard turned surface", Int. J. Mach. Tools Manufact., Vol. 38 (5-6), pp. 419, 1998.

[12] Niberg, A. N. " Wear Resistance of Sideways Strengthened by Burnishing", Soviet Engineering Research, Vol. 7, No. 5, pp. 67, 1987.

[13] Michael, P. C., Saka N., and Rabinowicz, E., " Burnishing and Adhesive wear of an Electrically Conductive Polyester-Carbon Film, Wear, 132, pp. 265, 1989.

[14] Hassan, A. M. and Sulieman, A-Dhifi, "Improvement in the Wear Resistance of Brass Components by the Ball Burnishing Process", J. of Material Processing Technology, Vol. 96 No. 1-3, Nov. 1, pp. 73-80, 1999.

[15] El-Axir M H. and El-Khabeery, M.M., " Influence of Orthogonal Burnishing Parameters on Surface Characteristics for Various Materials" Engineering research journal, Minoufia University, Faculty of engineering, Shebin El-Kom, Egypt, Vol. 25, No. 2, pp. 1110-1180, 2002.