Ball As a Finishing Tool "BALLIZING"

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ABSTRACT:

Ballizing is a microfinishing process, especially for cylindricall holes. The process is usually done by forcing a precision-ground metallic hard ball through a pre-machined hole. Ballizing is relatively new in the field of microfinishing processes and it has been used commercially on a large scale for its simplicity.

In the present work, experimental and theoretical investigations have been achieved to explore the significance of the ballizing process. The Ballizing force and the final hole size have been found experimentally and theoretically, and a good agreement has been found

INTRODUCTION :

The ballizing process is the forcing of precision ground tungsten carbide or hardened steel ball of a prescribed diameter through a slightly undersized hole. Fig. 1 shows the schematic arrangement of the ballizing process. The process is so simple, and only requires a ball to bring a hole to the required size under a high surface quality. This process is implemented in a few seconds. A good surface finish is very important not only for cosmetic purposes but also for longer component life, better surface hardness, fatigue life and corrosion resistance. Full capabilities of ballizing process are not yet mature due to the complexity of the prediction of the final hole size. The main parameters controlling the ballizing process are the interference value between the ball and the hole, material properties (yield stress, elastic modulus and hardness) and lubricants.

Nee and Venkatesh [1] concluded that for a particular hole diameter, some optimal interference value exists which gives the greatest improvement in surface finish. Some other papers have also been published in this field [3-11]. However, hardly, no attempt has been made towards the theoretical analysis of this process. Variation of microhardness, improvement of surface finish quality and roundness were the main parameters which have been studied through their experimental investigations. Proskuryakov and Valyaev, [9] focused their attention on the wall thickness as well as the value of interference on surface quality. Johnson and Travis [10] have found that both roundness and surface finish have been improved and the surface finish hardness increased substantially after ballizing. The only attempt which has been submitted to deal with the problem from the theoretical point of view was made by Nee [11]. He has considered the process as shearing of The surface asperities neglecting the effect of friction which is considered a vital factor controlling the ballizing load as mentioned before in his previous exerimental work [1]. The present work is an attempt to study the process experimentally and theoretically to formulate an analysis valid to deal with the ballizing process as computative values and not as absolute facts. To emphasize the validity of this study, the authors have also applied the present theoretical model on the other published results in this field

THEORETICAL ANALYSIS :

The ballizing load can be considered as the force required for elastic and plastic deformation of the material in the radial direction for certain depth. Part of the ballizing load is required to overcome the friction between the ball and the workpiece. The contact arc between the ball and the workpiece is ABC as shown in Fig. 1. In the arc AB elastic deformation takes place while in the arc BC the material deforms plastically.

Assuming that the ball is completely rigid, the radial displacement of the workpiece can be determined by considering it as a thick cylinder under internal pressure (p). Due to the interference between the ball and the cylinder, the radial displacement is given as [12].

$$u_r = (\delta_r/2) = \{a^2 p_r r / E (b^2 - r^2)\} \{(1-\upsilon) + (1+\upsilon)(b^2/r^2)\} \qquad (1)$$

Where:
  a   The internal radius   [m].
  b   The external radius   [m].
  μ Piosson's ratio,
  u_r the displacement at certain considered
      radius   [m].
  E   Modulus of elasticity [N/m²].
  δ_r The diametrial displacement at considered
      radius "r"   [m].

Considering $r = a$, the contact pressure p in Eq.(1) is
      as follows:

$$P = E\,(\delta/D)\,\{1/\,(\alpha^2+1)\,/\,(\alpha^2-1) + \upsilon\} \qquad (2)$$

Where, D Nominal internal diameter [m].
      The ratio between outer and inner diameters,

The pressure for plastic deformation in the arc BC
may be expressed by:

$$P = \sigma_y + E_1\,(\delta/D)\,\{1/\,(\alpha^2+1)\,/\,(\alpha^2-1) + \upsilon_1\} \qquad (3)$$

Where, σ_y The material yield stress   [N/m²],
      E_1 The slope of the sterss-strain
          curve in the plastic part   [N/m²],
      υ The piosson'S ratio for the plastic
          deformation.

Neglecting the effect of the elastic deformation and
considering that the process is rigid plastic defor-
mation, also assuming that the contact pressure is
constant and equal to yield strength of the material
(see Fig. 2). The ballizing force can be derived as
follows:

$$dF = p\,dA\,\{\sin\theta + \mu\cos\theta\} \qquad (4)$$

Where, dA   The incremental contact area   [m²],
      θ contact angle (see Fig.1),
      μ coefficient of friction.

The incremental contact area, dA, is given by:

$$dA = 2\pi R \cos\theta\,(R\,d\theta) \qquad (5)$$

Where, R Ball radius   [m].

Therefore, the ballizing force can be given by the
follwong equation:

$$F = \pi R^2 \sigma_y\,\{(\delta/R) + 2\mu\,(\delta/R)\} \qquad (6)$$

    When the ballizing process is completed,   the
material springs back elastically (Fig.2). The final
hole size is therefore less than the ball diameter by
the amount of the springback δ_s. The springback amount
δ_s is equal to the elastic displacement as shown in
Fig.2. This is because the unloading line is parallel
to the the elastic loading line (see Fig.2). Therefore,
the value of δ_s can be determined through Eq.(1) as
follows:

$$\delta_s = (\sigma_y/E)\,D\,\{(\alpha^2+1)\,/\,(\alpha^2-1) + \upsilon\} \qquad (7)$$

and the final hole size will be :

$$D_f = D_b - \delta_s \qquad (8)$$

Where, D_f Final hole diameter [m]

D_b Ball diameter [m]

EXPERIMENTAL WORK :

The internal surface of mild steel cylindrical workpieces was superfinished by using the ballizing process. The set up used is shown in Fig.3. The universal tesing machine (Model Wolpert, 200KN) was adopted to apply the ballizing force. Punch travel speed was controlled by controlling the hydraulic regulator of the machine at constant speed of 10mm/sec. The ballizing process was carried out without using Lubircant. Different ball sizes with diameters in the range12.7 mm. to 30.16mm. were used. With this set of balls, the workpieces were machined to give intererence values ranging from 50μm to 350μm. The workpiece dimensions were as follows:

Internal diameter according to ball size and interference,
External diameter   0.06 [m],
Height   0.05 [m].
The friction coefficient "μ" found to be 0.5, which is consistent with the asperities shearing during ballizing.
The workpiece tensile properties were determined by using the standard tensile test. The material properties were found to be as follows:
The yield stress $\delta_y = 450$ [KN/m²],
Modulus of elasticity E $= 200$ [GN/m²],
Surface roughness before and after ballizing was also measured. The ballizing loads vs punch travel were recorded by by the X-Y Plotter of the testing machine

RESULTS AND DISCUSSION :

The results of the present work are divided into three parts:
- Study the effect of the interference on the ballizing force,
- Study the accurate prediction of the final hole size, and
- Investigating the degree of improvement for surface quality after ballizing process.

The ballizing forces (F) versus the interference values between the ball and the cylinder (δ) are shown experimentally and theoretically in Fig. 4 Figure 4 shows that the ballizing force increases as the ball diameter increases for the same interference value, this might be due to the increase of contact

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arc length ABC, as previously expected from Eq. (6)

The trend of the results shown in Fig. 4 shows that the maximum ballizing force increased by increasing the interference value. This trend has been obtained under different ball diameters.

In order to generalize the benefits obtained from this work, the results are formulated, and plotted in Fig. 5, in dimensionless factors:

$$(F/\pi R^2 \sigma) \text{ and } (\delta/R).$$

This step has also been done for the previous experimental results obtained by [1],[2] and [11]. This adapted strategy is an endeavor to assess the ballizing process through a generalized form. Both of the experimental and theoretical results show that the factor (δ/R) is an effective factor which influences the ballizing force.

The hole diameter decreases after finishing the ballizing process due to the springback action of the material. The final hole diameter predicted by using Eq. (7) and Eq.(8) and the measured values are shown in Table 1. Comparing the measured and the predicted values a good agreement has been found.

The surface finish after the ballizing process has been improved by more than 87% (Ra after /Ra before = 0.13). This is shown through the strip records of surface profile before and after ballizing as shown in Fig. 6. This category of surface quality can not be achieved through any other machining process.

Table 1 : Experimental and Theoretical Final Hole
Size
Ball Diameter, D_b = 30. 16mm.,

δ,mm.	0.15	0.2	0.25	0.35	0.45
D_f(Eq.8) .mm.	30.011	30.011	30.011	30.011	30.011
D_f,measured mm,	30.012	30.0121	30.0122	30.01	30.0115

CONCLUSIONS :

1- The ballizing process proved its adequacy as a superfinishing technique vaild to deal with the hard material with the advantages of simplicity and high surface quality (0.4μm).

2- The theoretical model suggested in this paper submits a solution to control the ballizing process through the accurate prediction of load and final hole size.

3-   The ratio (δ/R) has been found to be a vital factor affecting the ballizing force.

REFERENCES :

1- Nee, A.Y.C and Venkatesh, V.C., "Bore Finishing-The Ballizing Process", J.Mech, Work Technol., Vol. 6 pp 215-226(1982).
2- Fattouh, M., "Some Investigations On the Ballizing Process", J. of Wear 134: Vol.2 pp 209-219(1989).
3- Gazan, G.A., "How To Make A Good Hole Better", SME Technical Paper MR 77, 461, (1977).
4- Gazan, G.A., "Better Holes By Ballizing", Tool Manuf. Eng., 57, pp 54-56 (1966).
5- Gazan, G.A., "Ballizing-A High Production Tool", Tool prod., Vol. 34,pp 89-90 (1966).
6- Robinson, J.M., "Ballizing, the Engineering of holes", Tool Manuf. Eng., Vol 48,pp 65-66,(1962).
7- Yuck, N.S, and Lee, B.N., "A Study On the Bore Finishing Of Cylinders By Burnishing", Proc. ICPE, pp 156-161, (1977).
8- Nee, A.Y.C., and Venkatesh, V.C., "A Study On the Ballizing Process", Ann. CIRP, 30 (1), pp 505-508, (1981).
9- Proskuryakov, Yu.G., and Valyaev, F.F., "Surface Finish When Internal Burnishing Holes With Considerable Interference", Machines and Tooling, Vol., XII No., 12, pp 37-39 (1983).
10- Johnson, W. and Travis, W., "High Speed Expansion and Bore Finishing of Austenitic Stainless Steel Tubes", Proc. Int., Conf, on Manufacturing Technology, ASTME, Dearborn pp 1433 (1984).
11- Nee, A.Y.C., "On the Development of Ballizing Nomograms", Int. J. Mach Tool Des. Res., Vol. 26, No 3, pp 293-306 (1986).
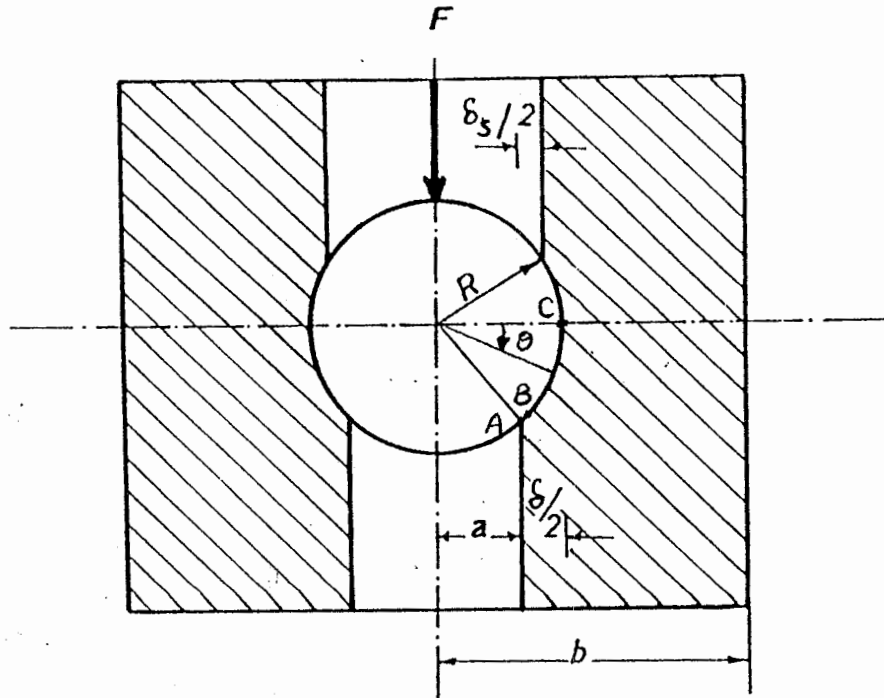12- Boresi, and Debottom, "Advanced Mechanics of Materials" John Wiley & sons, (1985).
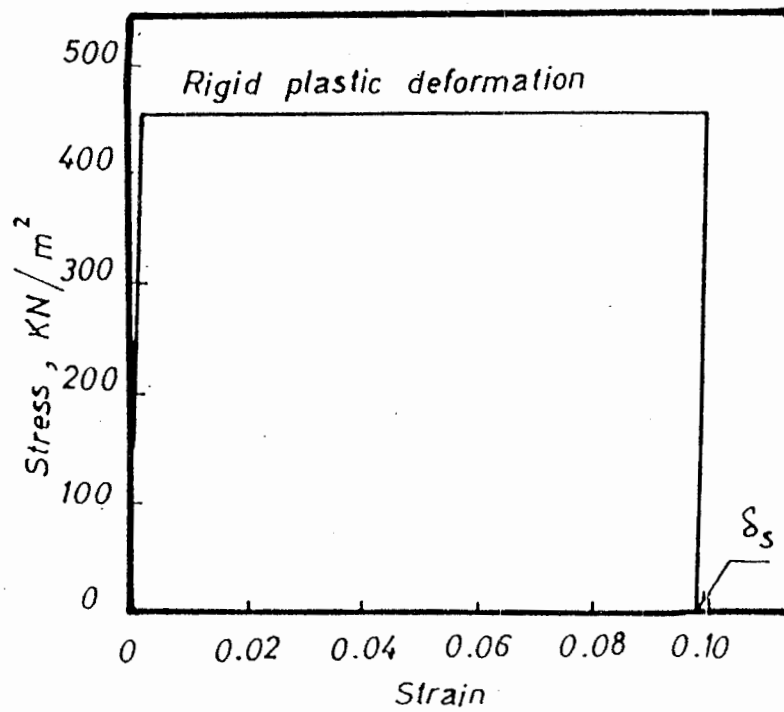
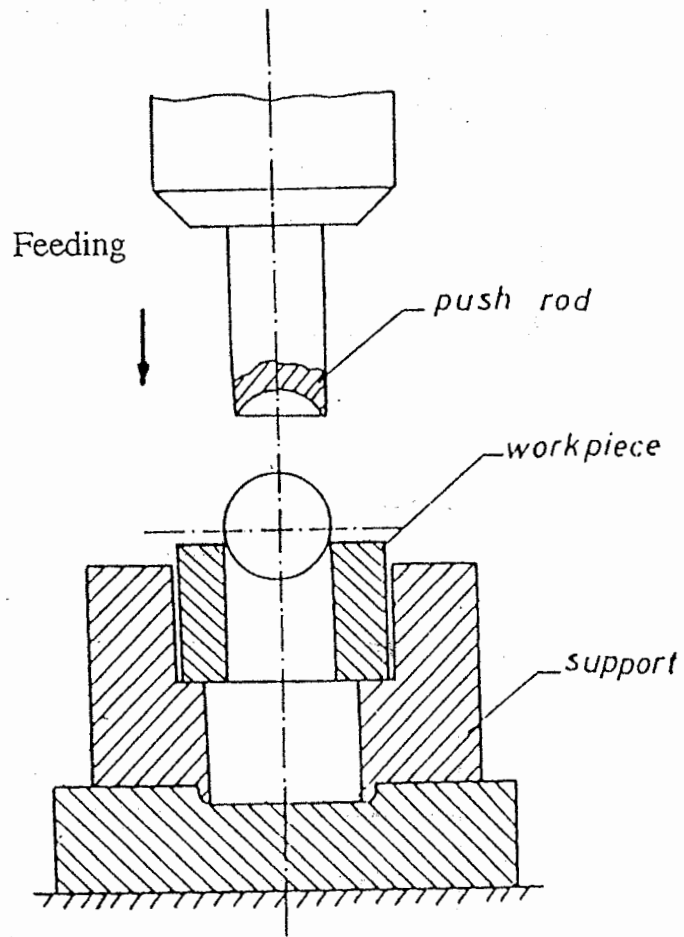Fig.1. Ballizing process.

Fig.2. Stress - strain curve.

Feeding

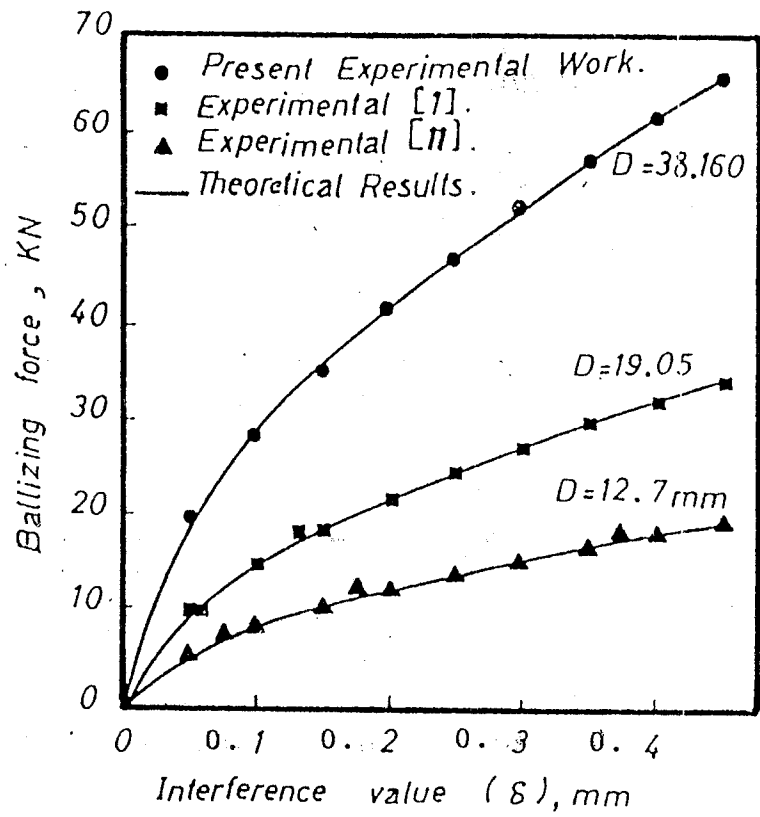push rod

workpiece

support

Fig.3. Schematic of the set up.

Fig.4. Effect of interference value on the ballizing force.
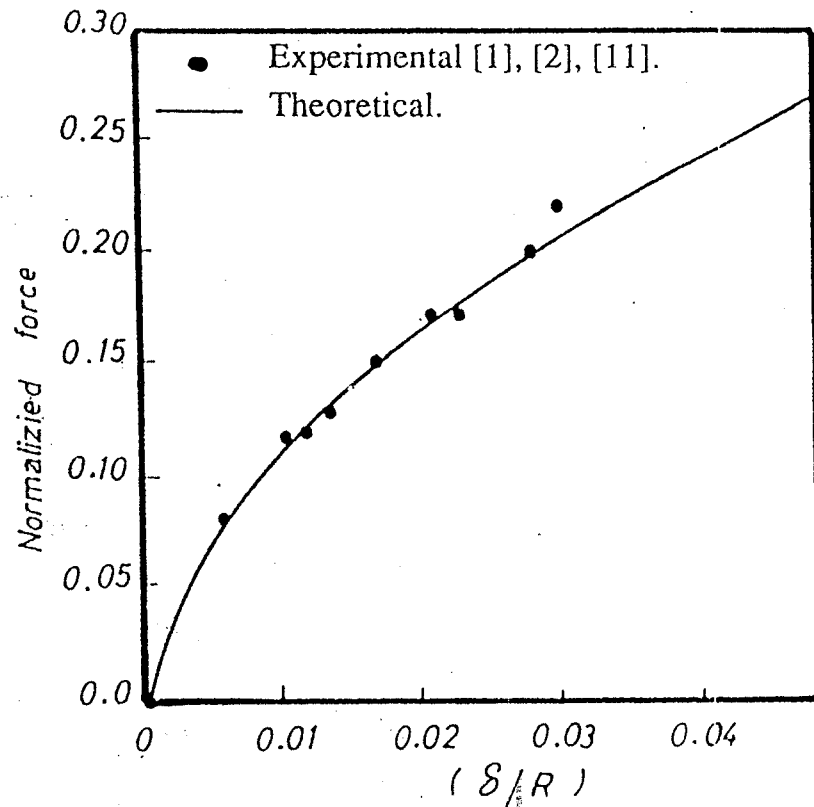
Fig.5. Normalized force $(F/\pi R^2 \delta)$ vs norm-alized interference (δ/R).
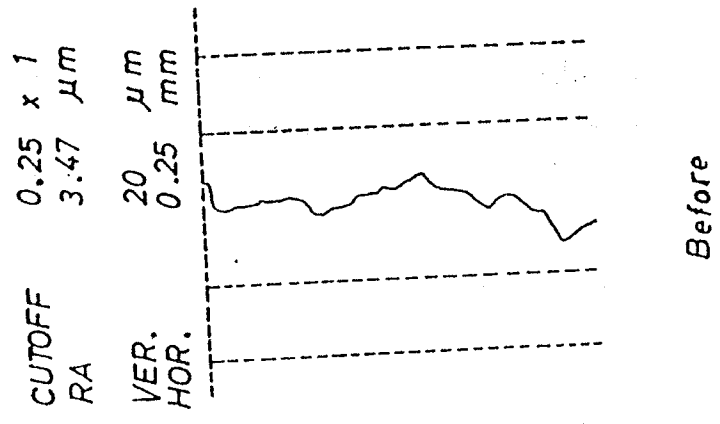
After

CUTOFF	0.25	x 1	μm
RA	0.44		μm
VER.	1		μm
HOR.	0.25		mm

Before

CUTOFF	0.25	x 1	μm
RA	3.47		μm
VER.	20		μm
HOR.	0.25		mm

Fig. 6. Surface roughness before and after ballzing.

الكــــره كــــأداه تشطيبيـــه

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ملخـــــص البحـــــث :

يتنـــاول البحـــث تقديــم دراســة عن احــدى طـرق التشطيــب الفائـــــق وهـو استخـــدام الكــره فى تشطيــب السطــوح الداخليــه (الدائريــه) عـــن طريـــق دفـع كـره من الصلــب أو الكاربيـــد داخـل الثقـب تحـت قـوى ضغـــط هيدروليكيــه، ممــا يكون لـه دور كبيـــر فى تحسيـــن السطــح المشغـل وكسبـــــه صـلاده عاليــه وهى طريقــه مبسطــه وتغنــي عن كثيـر من الطـرق المعقــــــدة المستخدمــه لمثــل هــذه النوعيــه من الثقــــــوب .

قــدم البحـــث النتائـج المعمليـه الناتجـــه من درجـه تشطيـب السطـح – القـــدره المستخدمــه ــ الارتـــداد المـرن وقــدم البحــث كذلك نمـوذج رياضــــى صالــح للتنبـــؤ بقــوة الدفـع اللازمـه لاجـراء العمليـه وكذلك قيّـم الارتـداد المـــرن حســـب الخلـوص المستخـــدم بين الكـــره والثقــب ، وطبـق هــــذا النمـوذج على النتائـــج العمليـه المستخدمـه من قبـل فى هــذا المجـال بواسطــــة باحثيــن آخريـــن وأظهـــر توافقـــا قويـا ممـا يدعـم أسلـوب المعالجـه الرياضيـه المستخدمـــــه .

وبهـــــذا يكـون البحـــث قـد اشتمـل على نتائـــج عمليـــه ومعـــــــادلات رياضيـــــه تسهــم كثيـــرا فى استخـدام أسلـوب التشطيـب بالكـــــره .