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Effects of the Applied Pressure and Pressing Speeds on the Total Resistance of the Compressibility Process

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ABSTRACT

The compaction apparatus is used in this study to measure the total resistance of particles during the compressibility process for approaching the real resistance of the particles in the ball mill and to simulate the grinding in an actual ball mill in order to be used for design purposes. The apparatus consists of two punches and a large die which a single punch pressing. The size reduction is measured because it gives an indication to the total resistance and the grinding product of the coarse particles of white cement clinker manufacture by Alkhomes refractory. The effect of the compaction applied pressure and compaction velocity are studied. Results indicated that the high total resistance (Tr) occurred at high compaction speed, low applied pressure and at increase the weight of a compacted material.

Keywords: compressibility process, pressing speeds, compaction particles resistance, total resistance

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تأثير الضغط المسلط وسرعة الضغط على المقاومة الكلية التي تنتج من الجزيئات اثناء عملية الانضغاطية

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الخلاصة

تم في هذا البحث دراسة تأثير الضغط المسلط والسرعة التي يتم بها تسليط الضغط على مقاومة الجزيئات الكبيرة الحجم خلال عملية الانضغاطية باستخدام قالب كبير متكون من مكبس علوي متحرك ومكبس اخر في الاسفل ثابت داخل أسطوانة تم تصميمه لهذا الغرض وهذا يصب في الوصول الى حقيقة ما يحدث من مقاومة للجزيئات داخل الطواحين ذات الكرات الصلبة والتي تلعب دور هام في عملية الطحن للجزيئات حيث تم استخدام جزيئات مادة السمنت الكلنكر المصنعة في مصنع السمنت لمدينة الخمس الليبية ذات الحجوم الكبيرة. أثبتت النتائج الخاصة بهذا البحث ان أكبر مقاومة تبديها الجزيئات عندما تكون سرعة الانضغاط عالية وايضا عندما يكون قيمة الضغط المسلط قليلة مقارنة بالكمية الموضوعة داخل الطواحين .

1- Introduction

Compressibility is the ability- of the material to reduce the volume under pressure; this is nearly what happens in the crushing and grinding of the coarse panicle inside the ball mill. Therefore, coarse particles of white cement clinker are used a and these particles need more than 100 kN to approach the compaction condition. While maximum capacity is 100 kN for our Instron machine.

The compression of powdered or granular material into cohesive mass during the formation of a compact is widely used. As pressure is applied, re-arrangement of powder particles takes place, within die, so that the large void are filled and interparticle; friction may be sufficient to cause fragmentation of the weaker particles. Further increase in pressure is believed to cause elastic and plastic deformation of the particles which also cause a fragmentation of the same primary particles. Therefore, it is considered that if particles of known size are compressed and then allowed to disintegrate, evidence of fragmentation or interparticle bonding might be obtained.

Size reduction is an important step in many processes by which raw materials are converted into final products. It may be the first operation in a chemical process or the last step before product packaging. Examples may be taken as; the preliminary grinding of phosphate rock in phosphoric acid-production, and the final grinding of clinker in the manufacture of cement. In chemical industry, size reduction is usually carried out to increase the surface area because in most reactions involving solid particles, the rate is directly proportional to the area of contact with the second phase.

2- Materials and Methods

Using a laboratory sieving machine (Retsch Ltd, UK) white cement clinker manufactured by Al-Khomes* cement industry from the following raw materials, 10 % sand, 10% clay and 80% limestone is classified into (-1100+900 µm), (-2000+1800 µm), (-2500+2100 µm), (-2800+2500 µm), (-3550+3350 µm) and (-4500+4000 µm). These fractions are the normal sizes of narrow range as follows; 1000, 1900, 2300, 2650, 3450 and 4250 µm. Compression is produced using a hydraulic universal testing machine (Model 1190, Instron Ltd, High Wycombe, U.K) fitted with 67.2mm stainless steel die diameter. It is decided to use hardened steel (55) for the punch and die cylinder to withstand the large applied-pressure and abrasion. By honing the die-wall with a fine stone, the groves in the surface had a depth of less than 0.5µm and 0.6µm, at the end of the experimentation. After every compaction measurement the die is demounted, and if damage to the die wall is perceptible to the naked eye, the die is honed, honing oil removed by rinsing with methyl ethyl ketone (MEK) followed by ultrasonic cleaned in ethanol and acetone in turn. The clearance between the die-wall and the punches is 0.2mm in the majority of tests.

3- Results and Discussion

It is possible to examine the grinding of the product of white cement clinker by compression process, if the size reduction ($\overline{\Delta X}$) during compressibility process was measured. This size reduction ($\overline{\Delta X}$) in the coarse particles is calculated from the following formula:

$$\overline{\Delta X} = \overline{X2} - \overline{X1} \qquad (1)$$

Where:

$\overline{X1}$: The mean particles size diameter after compression process.

$\overline{X2}$: The mean particles size diameter before compression process.

Both mean particles diameters ($\overline{X1}$ and $\overline{X2}$) are calculated from the moment of the sum of all the elementary areas of thickness (dx) about ordinate equals the sum of all the moments:

$$\overline{X} = \frac{\sum Xi \cdot \Delta Q}{\sum \Delta Q} \qquad (2)$$

Where:

Xi is the average size and ΔQ is the weight percentage in range (Alien, 1981).

When compaction pressure, P, is applied to the top punch a resisting pressure builds up in the powder or other materials, especially in the zone where the face of the moving top punch meets the wall of the die. The total resistance (Tr) has been found an important factor to cause a size reduction and the increment of the specific surface area. The total resistance of a compacted material consisted of:

a) Structure of the compacted material resistance (Sr).
b) Friction resistance (Fr). This includes the interparticles and particle-die wall frictions.
c) Air- entrapped resistance (Ar).

The best term that explains the total resistance (Tr) is (1/r), where (r) is the reduction ratio or the compaction ratio. Reduction ratio is calculated from the following formula:

$$r = 1 - \frac{H_f}{H_o} \tag{3}$$

Where:

(Hf) is final height of a compacted material and (Ho) is initial height of a compacted material.

Various compaction parameters are examined to find the success of this process to causing the size reduction and to approach the total resistance which effects the grinding of the coarse particles in the ball mill. These compaction parameters are studied separately and as shown respectively:

a) Weight of a Compacted Material:

The compression of white cement clinker, feed size fraction is 2650µm and 4250µm, have been conducted in a large die (see Fig. 1) under constant applied pressure (25.375 MPa) and constant compaction speed (0.5 cm/min.). The chosen weight in this study comprises a single bed (0.25 layers (L), 0.5L and O.75L) and packed bed (1L, 2L, 3L and 4L) as represented in Fig. 2. The weights are multiplied by the number of the layers.

The cumulative Weight percentage is calculated for each weight of fraction size and plotted versus the particle size for each fraction using the highly recommended method suggested by Hukki (1975), Abdul-Wahab (1990) and Limwong (2004). This method includes the plotting of the overall cumulative weight versus the size distribution of a cumulated product on a log-log scale and thus producing smooth curves. The curves are shown in Figs. 3-9. These figures show the distribution curve for the compaction product of feed fraction 2650 µm for various weight of a compacted material and compaction pressure, these curves are the same for another size particle.

In Fig. 3, it is shown that the distribution curve of 0.25 layers is a smooth convex curve, which is due to absence of the effect of interparticle friction force and the die-wall friction force. But Figs 4 and 5 illustrate the distribution curves of 0.5 and 0.75 layers, while the particles friction began to effect on the compaction process. Therefore, a slightly scattering on the convex curve happened. In the compression of cement clinker as layers, the distribution curve is largely scattered on the smooth convex curve as shown in Figs. (6-9). Thus scattering, because, of the friction forces began to influence strongly the compaction process.

But fig. (10) Represents how the total resistance (Tr) varies from a single bed to a packed bed for feed sizes (4000-4500 µm). However, the total resistance increases with the increase of the weight of compacted material, and this leads to a decrease in the reduction of particle size as concluded from Fig. (11). Actually, at the single bed (0.25, 0.5 and 0.75 layer) the particles are fragmentated easily because the total resistance is very small due to absence of friction resistance and air-entrapped resistance, so, this will lead to a high fragmentation to the particles as shown in fig. (11). The results for sizes (4000-4500 µm) of this section are tabulated in table (l) (Al-Khomes is a city located east of Libya).

Fig. 1 Compressibility die of coarse particles.

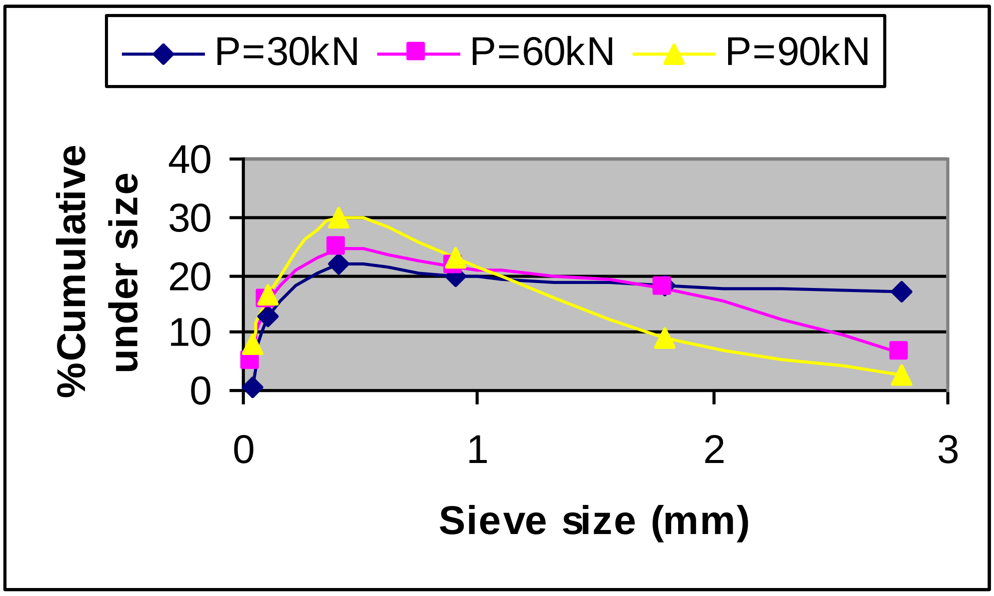

Fig. 2 Size Distribution of Cement Clinker for Different Compaction Applied Force (P) to The Feed Size (-2800+2500 μm) of 0.25 Layer.

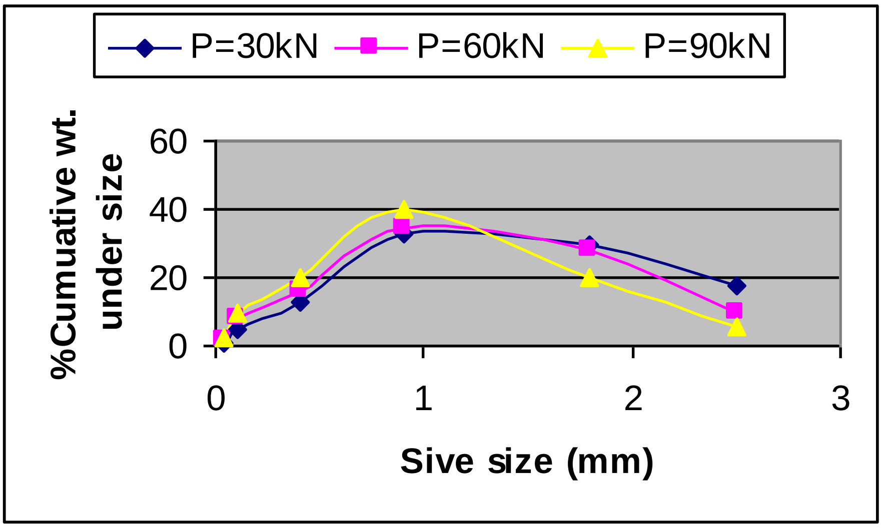

Fig. 3 Size Distribution of Cement Clinker for Different Compaction Applied Force (P) to The Feed Size (-2800+2500 µm) of 0.5 Layer.

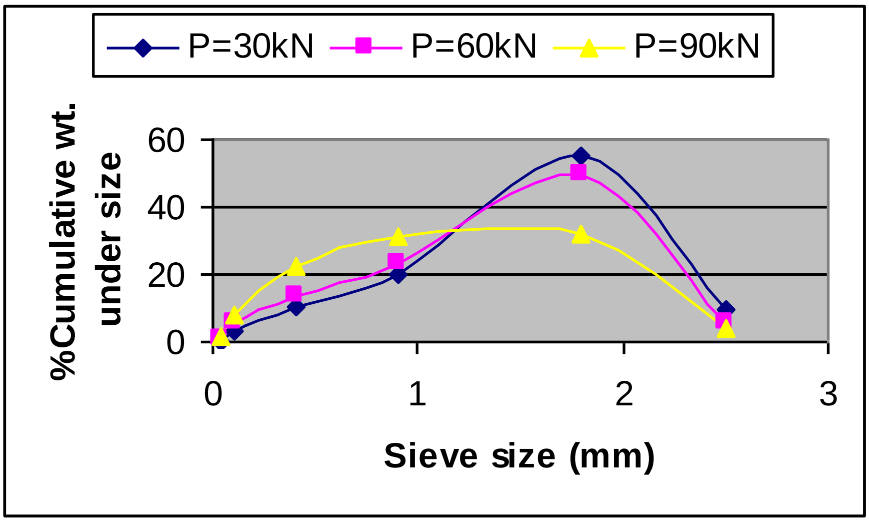

Fig. 5 Size Distribution of Cement Clinker for Different Compaction Applied Force (P) to The Feed Size (-2800+2500 µm) of 0.75 Layer.

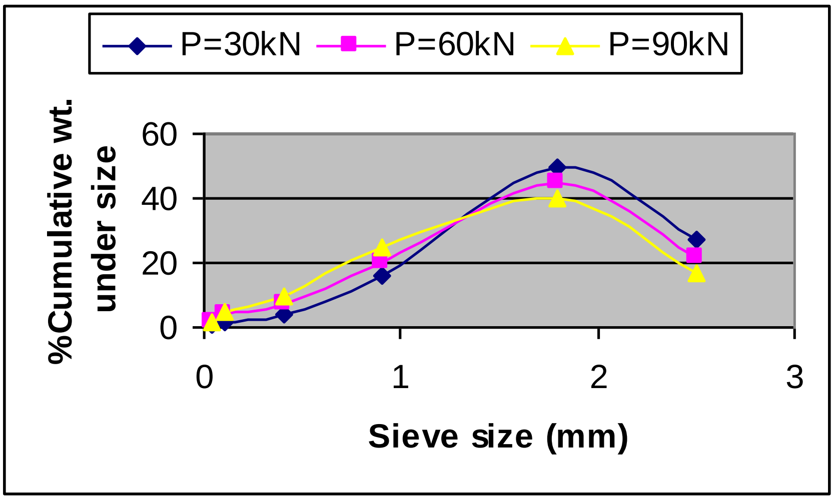

Fig. 4 Size Distribution of Cement Clinker for Different Compaction Applied Force (P) to The Feed Size (-2800+2500 μm) of 1 Layer.

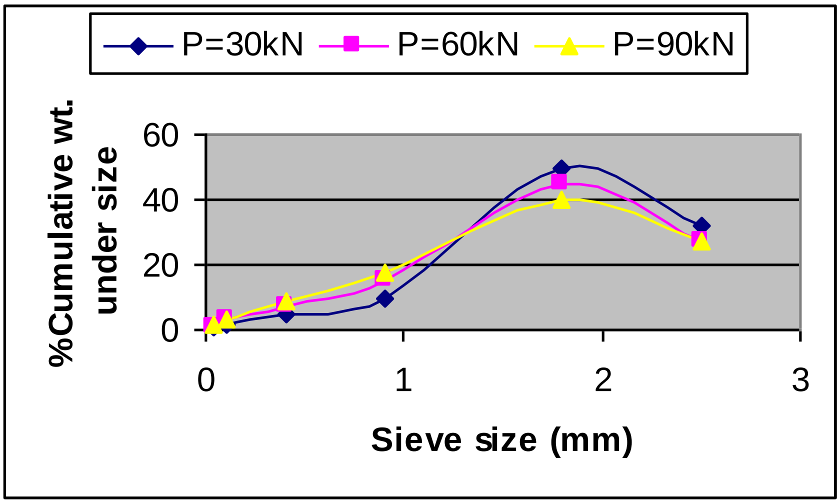

Fig. 5 Size Distribution of Cement Clinker for Different Compaction Applied Force (P) to The Feed Size (-2800+2500 μm) of 2 Layers.

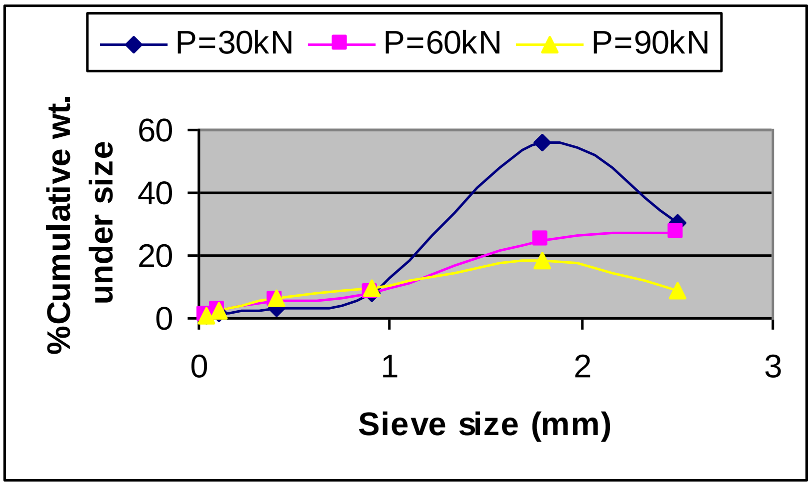

Fig. 6 Size Distribution of Cement Clinker for Different Applied Force (P) to The Feed Size (-2800+2500 µm) of 3 Layers.

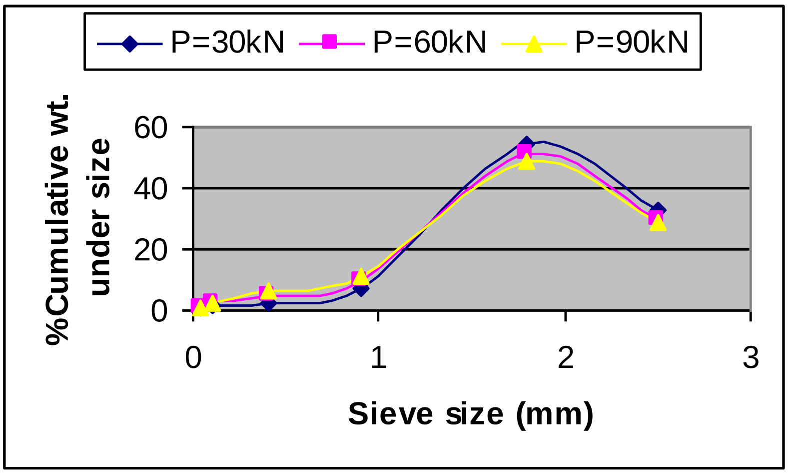

Fig. 7 Size Distribution of Cement Clinker for Different Applied Force (P) to The Feed Size (-2800+2500 µm) of 4 Layers.

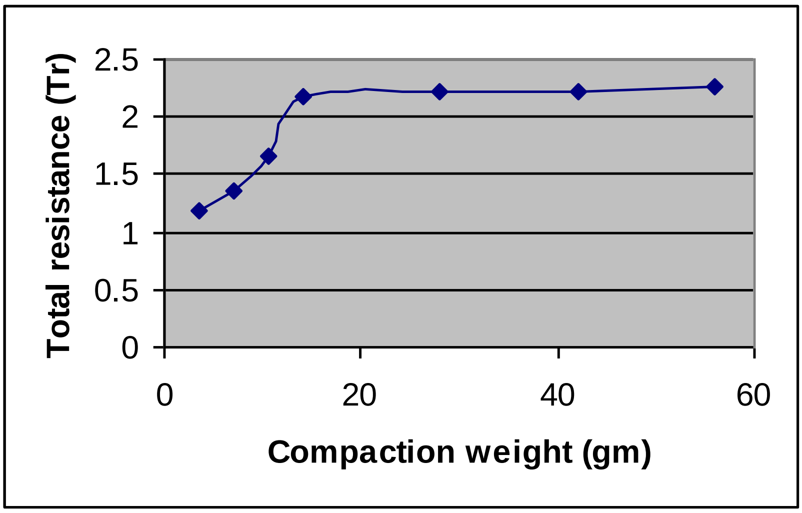

Fig. 8 The Total Resistance (Tr) During Compacted Different Weight of Cement Clinker for Feed Size (-4500+4000 µm).

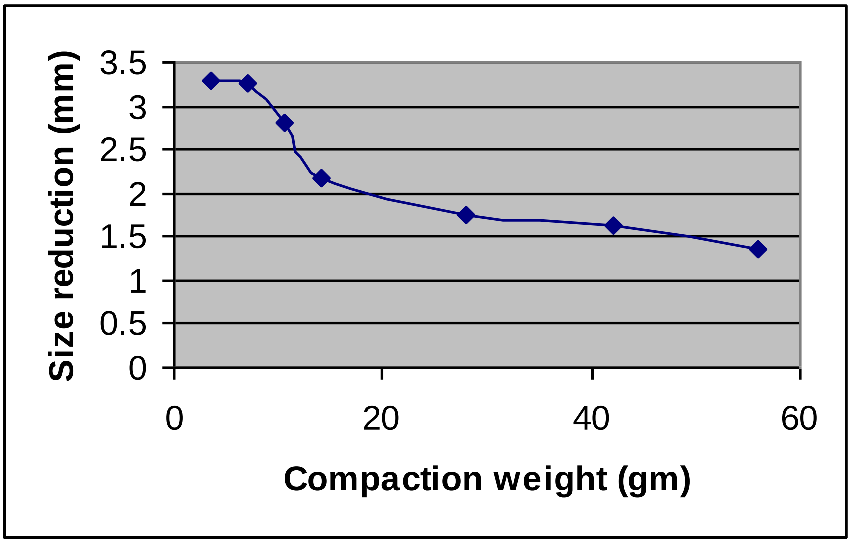

Fig. 9 The Variation of Size Reduction (X) During Compression of Different Weight of Feed Size (-4500+4000 µm) of Cement Clinker.

b) Compaction applied pressure:

Since the compaction applied pressure more than any other factor largely controls the density and the resulting mechanical properties of final products, knowledge of the relationship between compaction applied pressure and the material properties is very important.

To estimate the increase of size reduction for a particle size distribution, a better description should be given for fragmentation process. Fragmentation has been defined as the,-ton-nation of smaller, discrete particles from initial material. This implies that the characterization method should give direct information about the number of cleavages in particle after submission to compaction pressure.

A sieve fraction of white cement clinkers is used, which has a size range of 4000 - 4500µm with weight represent as the fourth layers. The compaction velocity is constant (0.5 cm/min) and the compaction applied pressure has a range from 2-25 MPa in this study. The total resistance (TR) decreased with increasing the applied pressure as seen in Fig. (14). It can be concluded from this figure that the curve becomes linear while it reached the critical pressure of 10 MPa and the high total resistance takes place at low applied pressure due to the high structure resistance (which represent the total elasticity of the wholly compact) and the friction resistance. However, this relation will lead to a linear relation between the size reductions with increase of the compaction applied pressure as shown in Fig. (15). Actually, the interparticles friction and particle-die wall friction forces are responsible for increasing the fragmentation of coarse particles.

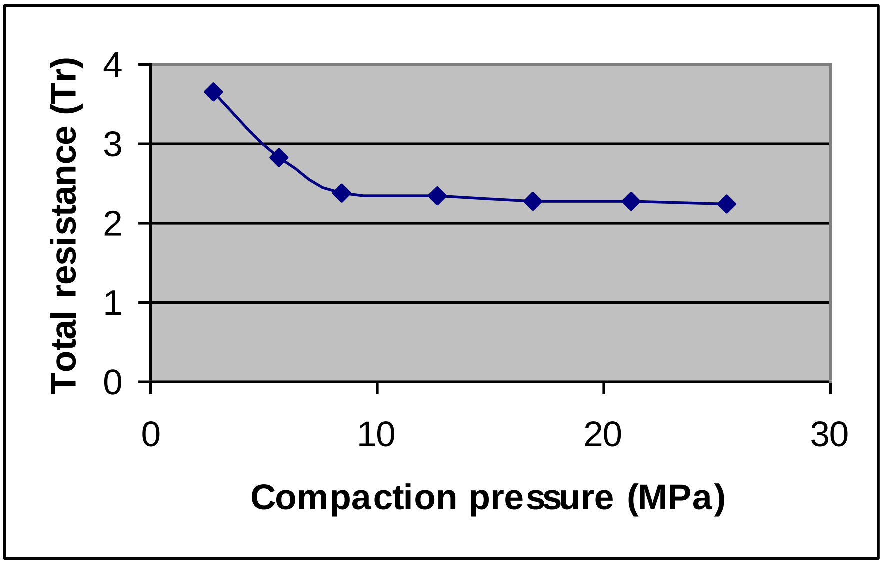

Fig. 12 The Variation of Total Resistance (Tr) with the Compaction Pressure for Feed Size (-4500+4000 µM) of Cement Clinker.

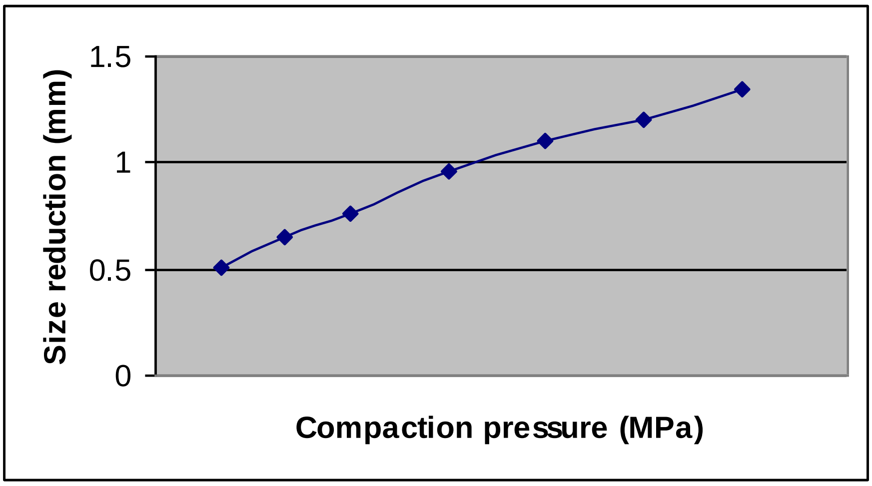

Fig. 15 Represents the Relationship between the Size Reduction with the Compaction Applied Pressure for Feed Size (-4500+4000 µm) of Cement Clinker

d) Compaction velocity:

Air entrapped inside the pores of the powder compact was found to be a source of cracks in powder compacts and is called laminations (Long and Alderton 1960, James and Newton 1983, and At-Jewaree and Chandler (1990)). This was attributed to the high compaction velocity, which was absent in the last work. In this work, the size reduction ($\overline{\Delta X}$) is examined at different compaction velocities and the effect of air entrapped to the fragmentation of the coarse particles. However, the entrapping of air inside the pores of the particles is found to increase the total resistance of the powder during the compressibility process as shown in Fig. (16). this resistance will lead to a small fragmentation of the coarse particles, because they reduce the total applied pressure which reached to the single particles. Supporting the above evidence, it is found that the size reduction decreasing with the increasing of the compaction velocity as illustrated in Fig. (17). The test is done at constant applied pressure up to 25.375 MPa and a constant weight equal to 44 gm as four layers to a size range from 2100 to 2500µm, but at different speed ranging from 0.5 to 50 cm/min.

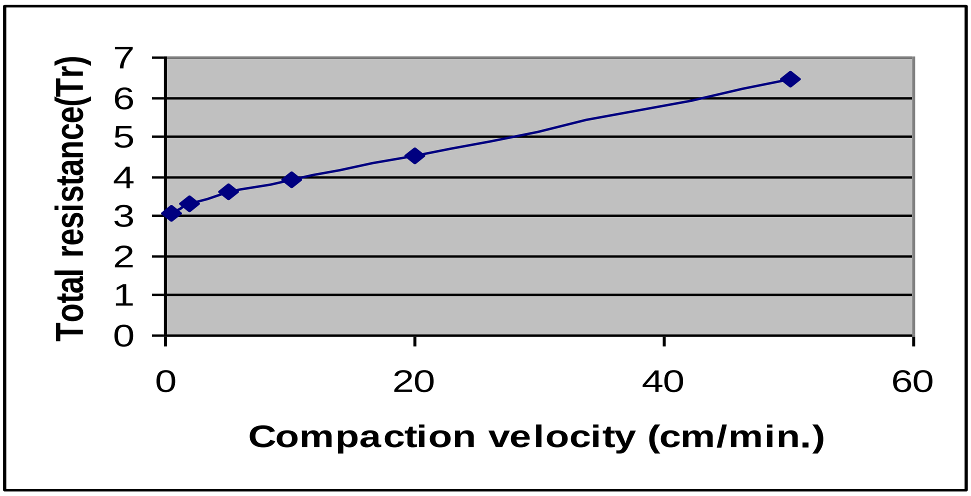

Fig. 16 Represent the Relationship between the Compaction Velocities and the Total Resistance (Tr) for Feed Size (-2500+2100 µm).

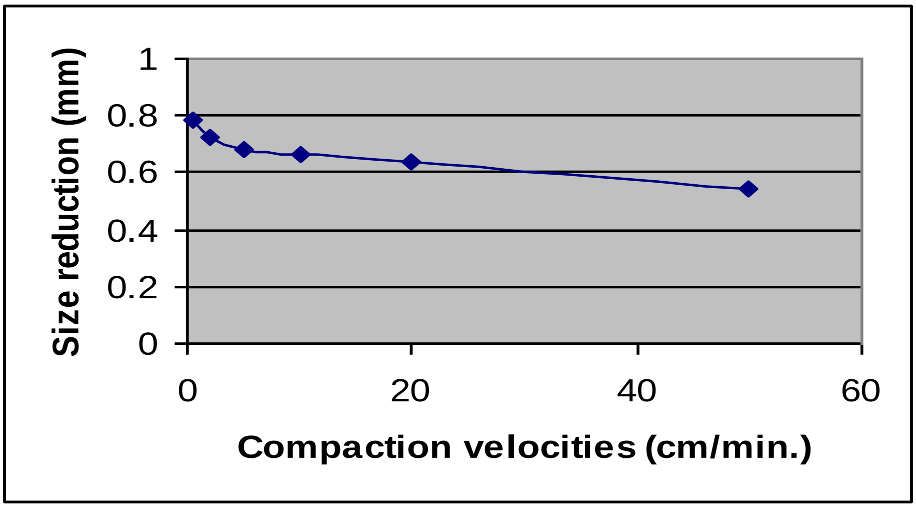

Fig. 17 The Variation of the Size Reduction of Particles with the Compaction Velocities for Feed Size (-2500+2100 μm).

4- Conclusions

The following conclusions are drawn out from the present study:

1) The increment at the size reduction (ΔX) means decrease in the total resistance of the compact materials. It is found that the maximum in the reduction size of the coarse particles at higher applied pressure, slower compaction velocities and at reducing the weight of compacted material (see Figs. 11, 15 & 17).
2) It is possible to estimate the total resistance Tr (1/r) during the powder compaction by measuring the inverse of the compaction ratio (r). The total resistance is mainly depending on the structure of the compacted material and the particle frictions.
3) It is obvious that for a certain particle size, the higher the compaction load, the more fragmentation will occur (see Fig. 15). On the other hand, one should forget that fragmentation cannot take place when porosity drowns near zero. Thus, considering fragmentation to be a function of particle size and porosity, it is clear from Fig. (13), that the large particles have more fragment than the smaller particle of white cement clinker.

4) It may be concluded that compaction apparatus is good enough to cause a size reduction in the coarse particles and for approaching the real total resistance of the materials inside the ball mill.

5- References

[1]. Hazim Al-Jewaree A.M, "Cracks in powder compacts M.Phil". Thesis, University of Newcastle upon Tyne – England, U.K.(1990)

[2]. Hazim Al-Jewaree A.M and Chandler, H.W. "Air Entrapment: A Source of Lamination during Pressing," *Br. Ceramic Trans J*, Vol. 89, p207-210. U.K, (1990)

[3]. Hazim Al-Jewaree A.M,"An Investigation into the compaction of powders", Ph.D. Dissertation, University of Baghdad, College of Eng., Iraq. (1996).

[4]. Šantl,M. and *et al.* "A compressibility and compactibility study of real tableting mixtures: The effect of granule particle size", *Acta Pharm., Vol.*(62) , pp 325–340.(2012)

[5]. Iman M.H. and et.al " The effect of particle size on compressibility of Cinnamon Granules", *Journal of applied and Industrial Science*, vol.3 (4). ISSN: 2328-4595, P 150-153. (2015).