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Technical Note

Some aspects on albite grinding and liberation

F.H. Abd EL-Rahiem*

Central Metallurgical Research and Development Institute, P.O. Box 87, Helwan, Cairo, Egypt

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ABSTRACT

For many products or ore products rigorous demands are made by, customers or beneficiation engineers, on the range and width of the particle size distribution. In order to achieve the right particle size distribution in the production process a laboratory tests are often necessary. Other aspects influencing the grinding process are also discussed. The liberation of ores is a well known example of the dependence of the grinding product properties on the particle size.The optimum grinding media of albite is limited to 9kg, grinding time 9min and filling voids ratio 2:1 to reach liberation size(-0.25+0.045mm).

Keywords: Albite; Grinding; Rod mill; Liberation size

1. INTRODUCTION

The purpose of the grinding process is to reduce particle size. In doing so, we are concerned about how to meet the objective with the minimum energy input and minimum slime production. Obviously, a finer product requires more energy input, but the same energy input does not necessarily produce the same degree of size reduction. Grinding processes operate by applying stress to individual particles so as to induce breakage. This requires that particles first be appropriately located to receive the stress. Particle placement is relatively simple at large sizes-in Jaw crusher for example. This ideal approach is, unfortunately, quite impractical in fine grinding and energy input to the mill is required to provide both functions. In the case of media milling, energy is supplied to the mill so as to agitate the media. Collisions between the media elements provide the stressing action while random motion of media and particles is relied upon to effect proper particle placement. To a considerable extent, there two functions present conflicting requirements, especially with respect to media size. Increasing media size increases the breakage stresses available per collision but decreases the number of media elements in the mill. There by reducing the collision frequency. The Best operating conditions generally involve a compromise between there requirements. An important consequence is that the process is highly inefficient in terms of energy utilization (Farat, 2002).

There are many variables that determine the ultimate outcome of the grinding process. These include material properties such as strength, hardness, brittleness, etc. The other variables are mostly related to the condition under which particles are subjected to breakage. In the case of media milling, these include the particle loading, the feed particle size, the rotational speed, the media size, the media loading, the solid concentration, etc. Breakage of particles occurs as a result of applied stress, which originates from energy input to the grinding device. However, the effectiveness of the breakage action does not depend on the level of energy input alone. The nature of the energy input also plays an important role. Kwade *et al.* (1996), have introduced the concept of energy intensity as a critical factor in determining whether or not stress application actually loads to breakage. Breakage rates are determined by stress frequency, modified by the stress intensity. Relationships between the stress intensity and frequency and operating conditions have been proposed (Blecher *et al.*, 1996; Blecker *et al.*, 1997).The specific energy depends on the product of the stress frequency and stress intensity, both of which vary with grinding conditions. Becker *et al.* (1997), showed that, for a fixed energy input, there is an optimum stress intensity that provides the most size reduction.

In many cases, the specific rate of breakage for any size is found to be independent of time and the extent of grinding i.e. the process follows first-order kinetics (Hogg, 2000). There are, however, many instances of rates that either increase or decrease with time. Acceleration of breakage has been observed in

* Corresponding author. E-mail: rababrashad2003@yahoo.com

wet grinding test in tumbling ball mills and is probably due to changes in the environment inside in the mill. Deceleration of the breakage rate is often encountered in prolonged grinding and appears to result from the accumulation of fine particles, which produce some kind of cushioning effect (Hogg, 2000).

The form of the breakage distribution is strongly affected by the breakage mechanism. It is generally considered that there are three breakage mechanisms which are important in media milling: fracture, chipping and abrasion (Crabtree, 1994). Fracture refers to the complete disintegration of a particle; however chipping refers to removal of fragments from edges and corners. While abrasion involves the uniform removal of surface material due to wear. Fracture leads to disappearance of the original particle, which replace by a complete suite of smaller fragments. Chipping and abrasion both lead to the appearance of fine particles along with the original particle, which slowly decreases in size. The chipping and abrasion mechanisms are sometimes lumped together as attrition. Trangsathitkulchai *et al.* (1985), reported that increases in the breakage rates often occur when the slurry is rather dilute. On other hand, breakage rates tend to decrease when the slurry become too thick.

The aim of this study is to grind albite ore near the liberation size and minimizing the 200 mesh (74μm) fraction using "rod mill".

2. EXPERIMENTAL

Albite (sodium feldspar) representative sample was brought from Sinai Peninsula, Egypt. A cylindrical rod mill was used in this study. It has the following dimensions 40x120cm and its volume is 150cm^3. The grinding media is steel rods each of the following dimensions, the mean diameter is 20.85cm and mean length is 29.35cm, and hence its volume is 100.16cm^3, and its mean weight is 753.8gm.

3. RESULTS AND DISCUSSION

A representative sample of Albite (sodium feldspar) was classified by screens, and the size distribution of this original sample is shown in Figure 1. It is clear that the top size is about 4mm, and its D_{50} is 0.64mm. However its content of 0.074mm is about 10%. The spread of sizes is some what large, because D_{90}/ D_{10} = 2000/ 82 ~24.

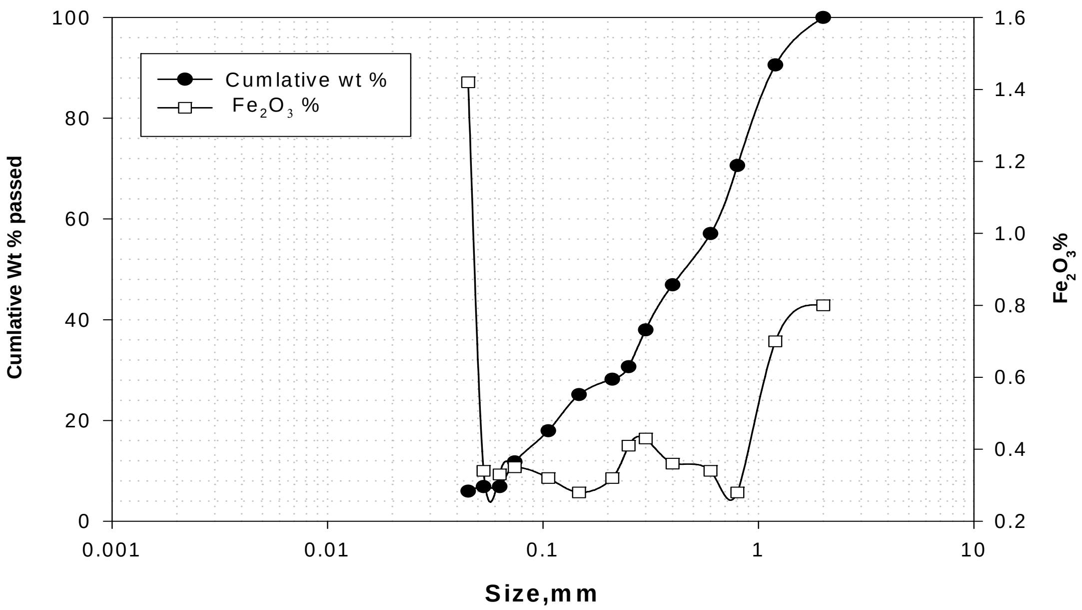

Figure1. Screen analysis of the original sample

The screen analysis of the albite sample is shown in Figure 1. It is also clear that, the coarser size has the higher iron oxide, as impurity, than the finest size. This is because albite is more friable than the iron bearing mineral. It is clear that, the iron oxide increases to 0.41%with decreasing the grain size from -2.0+0.25mm. The iron oxide is decreased to about 0.3%with decreasing the grain size from 0.25 to 0.045mm. On the other hand, the iron oxide increases again with decreasing grain size to -0.045mm. This clearly indicates the considerable liberation size that was achieved by lowering the size from 0.25 to 0.045mm.

Batches of the original representative sample of ~500gm each were prepared as a feed for the different grinding test.

3.1. The effect of grinding time

Batches of constant weight were added to the same weight of water to have solid / liquid of 1:1 (w/w) that is forming filling ratio of 100%, where the voids between the 12 rods are of 248cm^3 and the volume of the material is 640 / 2.58 = 248cm^3. The specific gravity of soda feldspar is 2.58. Each test at different retention times from 2min to 15min, as grinding time, was separately classified on the same series of screens. The screened products were dried, and weighed in Figure 2.

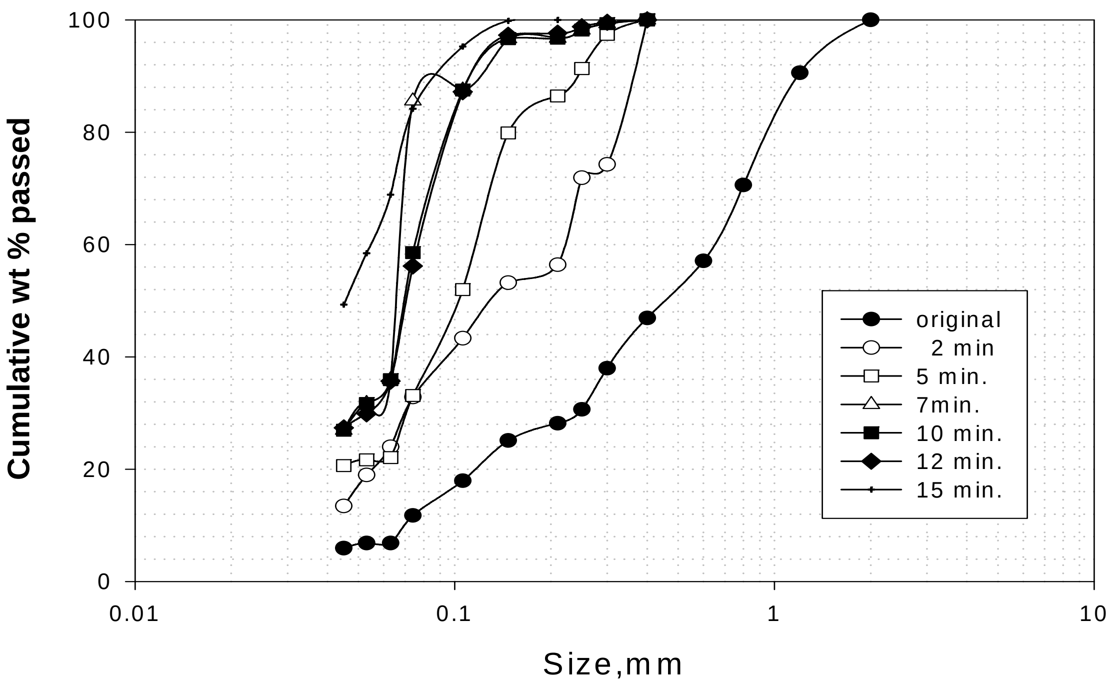

Figure 2. Effect of grinding time at S/L ratio 1:1 # 12 rod

It is clear that the increase of the grinding time from zero to 15min decreased value of D_{50} from 640 to 54µm respectively. However, the values of D_{90}decreased from 2000 to 120µm, i.e. the reduction ratio increased by increasing the grinding time. This increase in reduction ratio may be due to the increase in power and affected the coarser particles in the feed, and created new particles of finer sizes as shown in Figure 3. The new particles passed from 600µm resulted from 2 min grinding, it reached a constant value of 53%. However the new particles passed from 400µm reached its constant at 5min grinding time and that new particles passed from 250µm reached more than 68% at 7min and increased gradually. Although, the finer sizes i.e. 100µm and 74µm started new particles created by increasing the time of grinding, slowly, then increased without any constant value to reach more than 80% and 60% for these two finer sizes. This increase in their percentage is on the expenses of the other coarser sizes. The higher percentage of the size 74µm (i.e. 200 mesh) as a new particles affected the preceding beneficiation processes such as flotation and magnetic separation.

For this reason the grinding time(retention time) is limited by 7min, where maximum new particles of the liberation size (i.e.250μm) was produced from the grinding process. To confirm the selection of 7min as a retention time of grinding, see Figure 3, where the cumulative weight percent retained the liberation size (250μm) as well as these sizes higher than it decreased sharply to very minimum values 0%, 0.37% and 4.5% for those sizes above it, and that retained on 74μm is ~75%, which is of a close sizes (see the spread ratio curve) Figure 4, i.e. D_{90}/D_{10}.

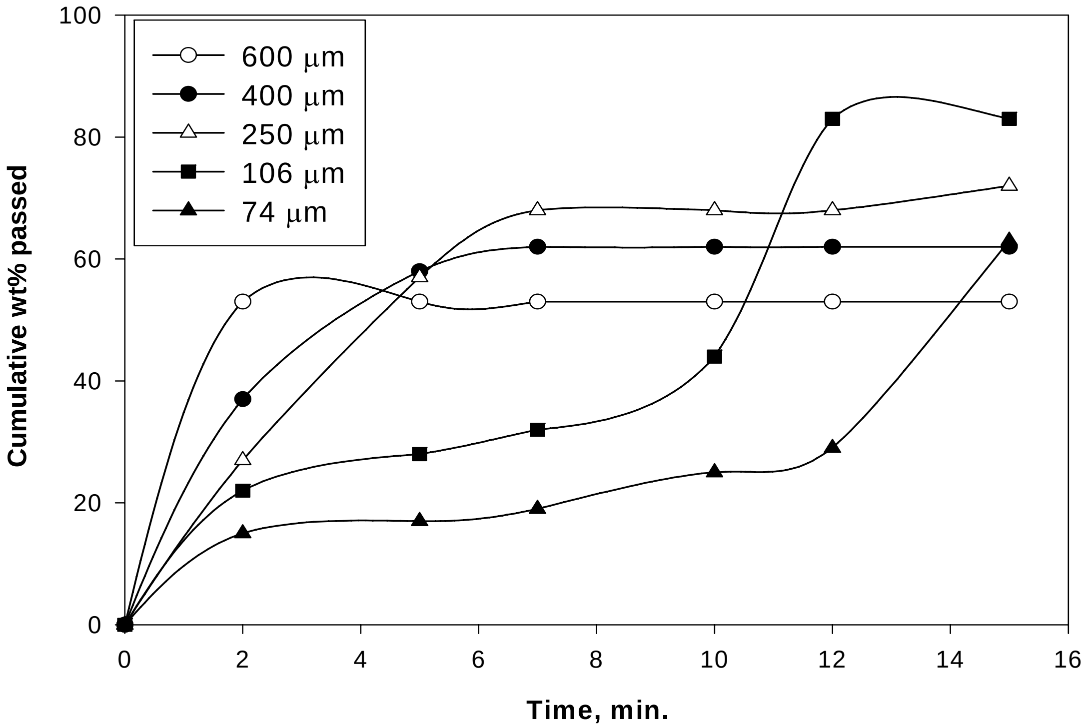

Figure 3. Cumulative wt% of new particles passed results from changing the time of grinding (retention time)

Which is about 7, which means after disliming (removal of 74μm) it decreased to about 3 in the final concentrate resulted from the pilot test (Aziza, 2003)

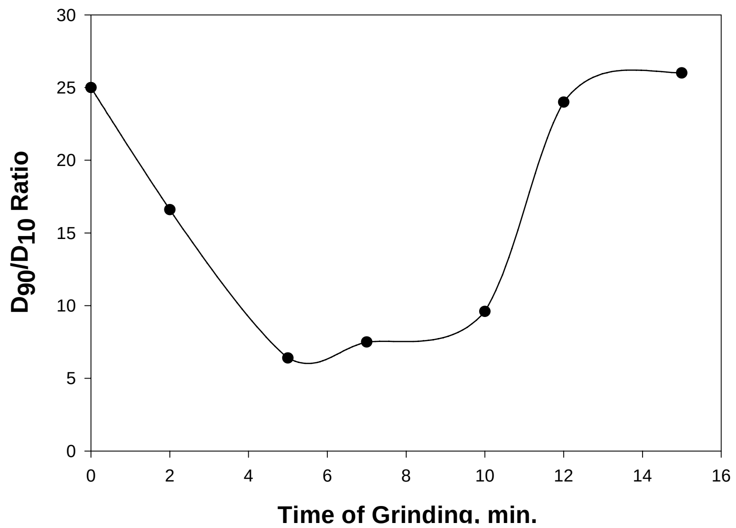

Figure 4. The spread ratio curve

However the results of D_{90}, D_{50} and D_{10} shown in Figure 5, from which it is obvious that the values of D_{90} and D_{50} decreased sharply by increasing the grinding time (retention time) up to 7min, then decreased gradually on increasing the retention time up to 15min This may be due to the decrease of coarser particles that subjected to the hit of the rods, see Figure 6, that related the cumulative weight percent retained on the different sizes (coarser than the liberation size) i.e., 600µm, 400µm and 250µm which dropped almost to zero at 7min and higher time.

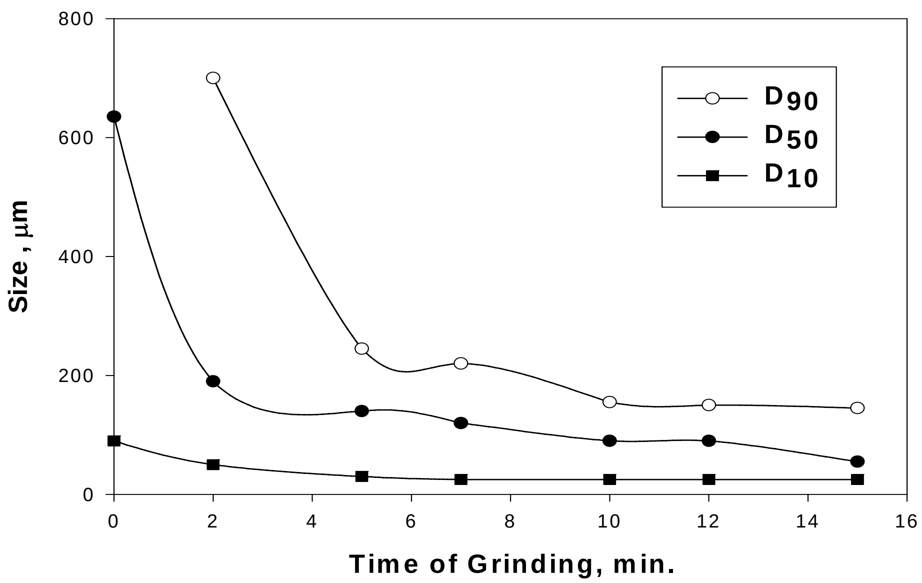

Figure 5. Effect of the change of grinding time

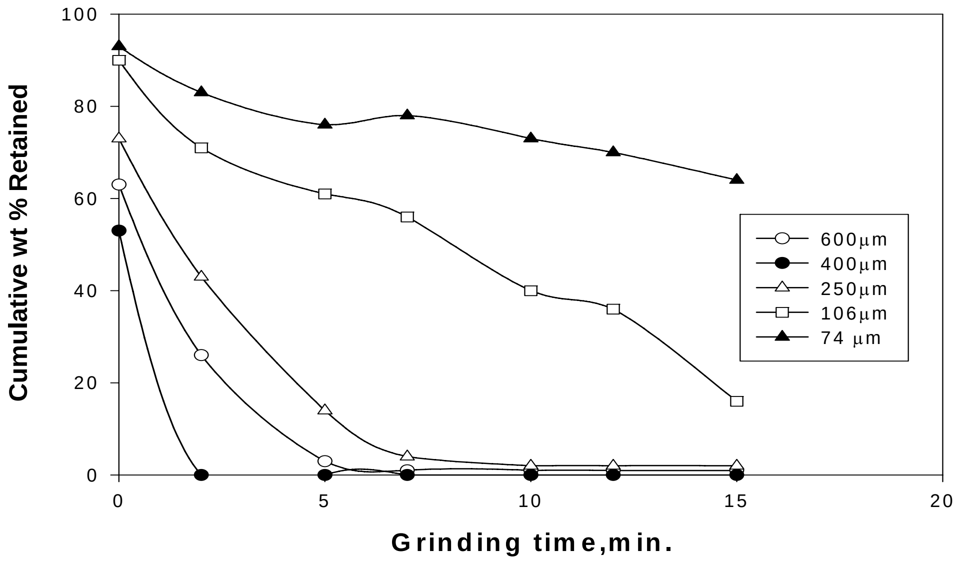

Figure 6. Effect of the change of grinding time on the cumulative weight % retained

3.2. The effect of the weight of grinding media

Batches of 640gm representative sample were fed to the rod mill with the same weight of water to keep solid / liquid ratio constant, and at 7min as grinding time. The number of rods was changed and hence the weight of grinding media changed from ~3kg up to ~9kg. The results of changing the weight of grinding media as, cumulative weight percent for different sizes of grinding products, were shown in Figure 7, from which it is clear, that the increase in the weight of grinding media, decreased the values of D_{90} and D_{50} very sharp decrease from 2000μm to 205μm at 0 and 9kg respectively.

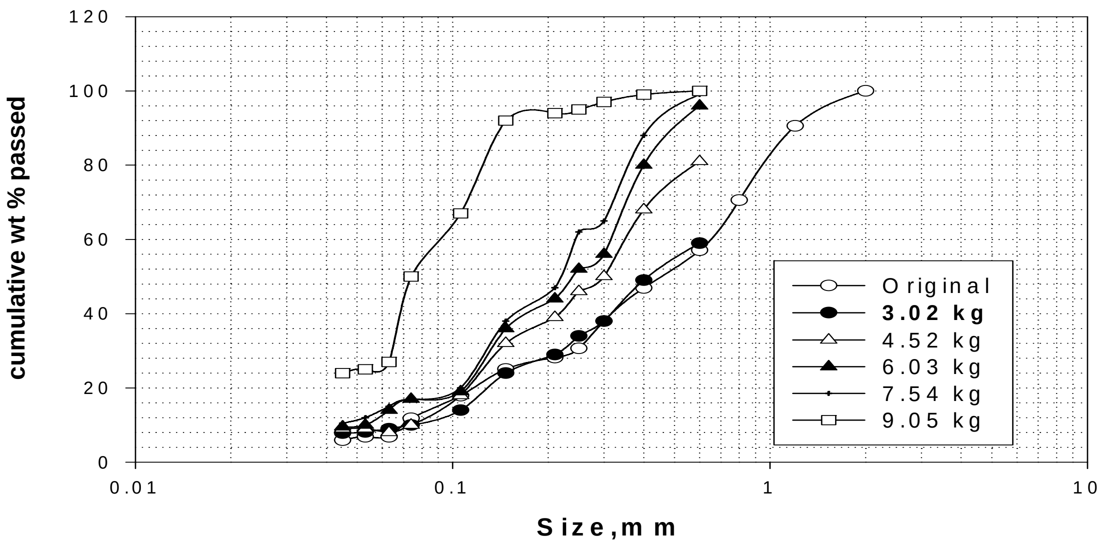

Figure 7. Effect of the changing the weight of grinding medium as cumulative weight percent for different sizes of grinding product

In case of D_{50} values which decrease from 640μm to 120μm at 0 and 9kg, but that decrease in the values of D_{10} are very small decrease i.e. from 96μm to 12μm for the same weights of grinding media mentioned before (Figure 8). The sharp decreases in D_{90} and D_{50} by increasing the weight of grinding media may be due to that the falling weights affected the coarser particles and create medium particle size as the usual in case of rod mills, which create very small amount of finer sizes. However, the new particles resulted from increasing the weight media passed from 600μm, 400μm, 250μm, 106μm and 74μm increased sharply for that of the three larger sizes, and increased gradually for the last two finer sizes in Figure 9. These results confirmed the action of rod mills that affected coarser sizes, and the finer sizes were protected by the coarser particles. Therefore the gradual increase in the two finer size may be due to the action of abrasion action that occurred in the ascending zone. However, the cumulative wt% retained shown in Figure 10, decreased sharply by increasing the weight of grinding media from 3kg up to 9kg in the case of the three coarse size mentioned before (i.e. 600μm, 400μm and 250μm). The Breakage of the coarse particle resulted in some what intermediate particles, not finer

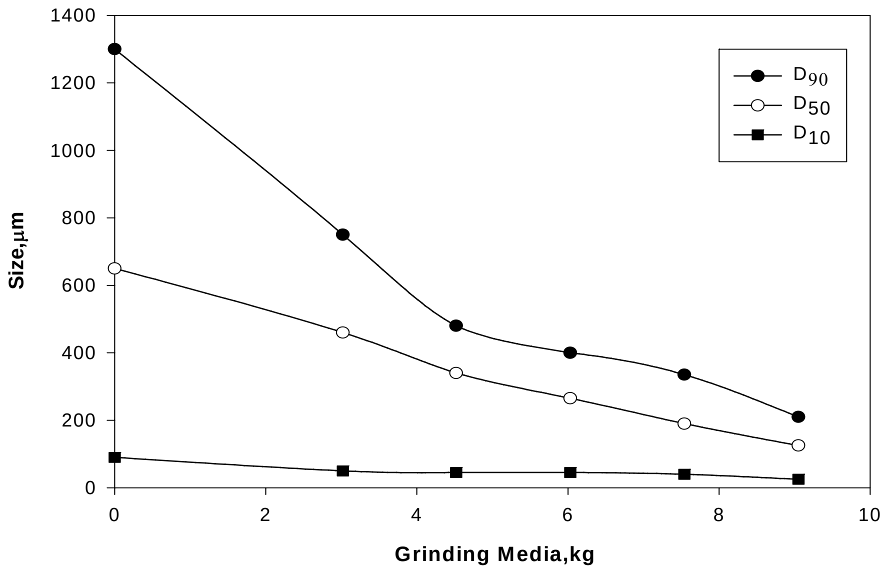

Figure 8. Effect of weight media on the size

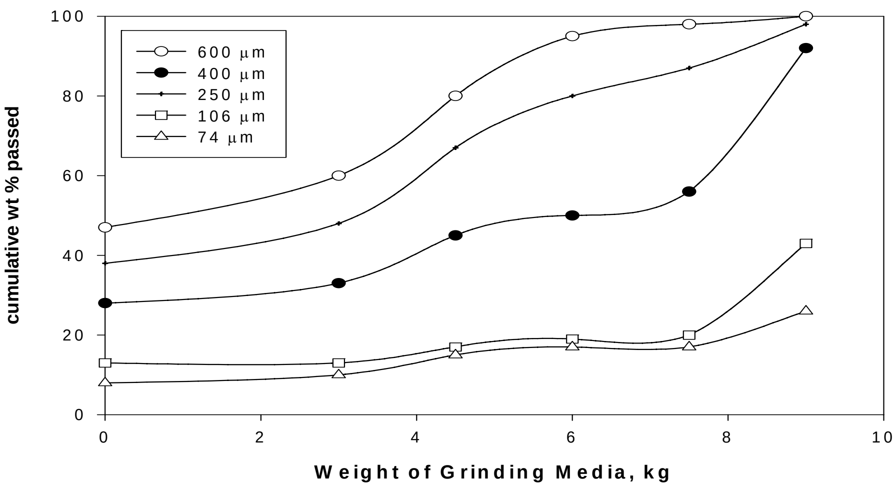

Figure 9. Effect of weight media on the cumulative weight % passed

Particles as clear from the cumulative weight percent, the two finer sizes (i.e. 106μm and 74μm) decreased gradually by increasing the weight of the grinding media from 3kg up to 7.5kg, then at higher weight of the grinding media (9kg). The reduction increases by increasing the weight of grinding media from 1.5 up to ~10 times at 3kg and 9kg respectively.

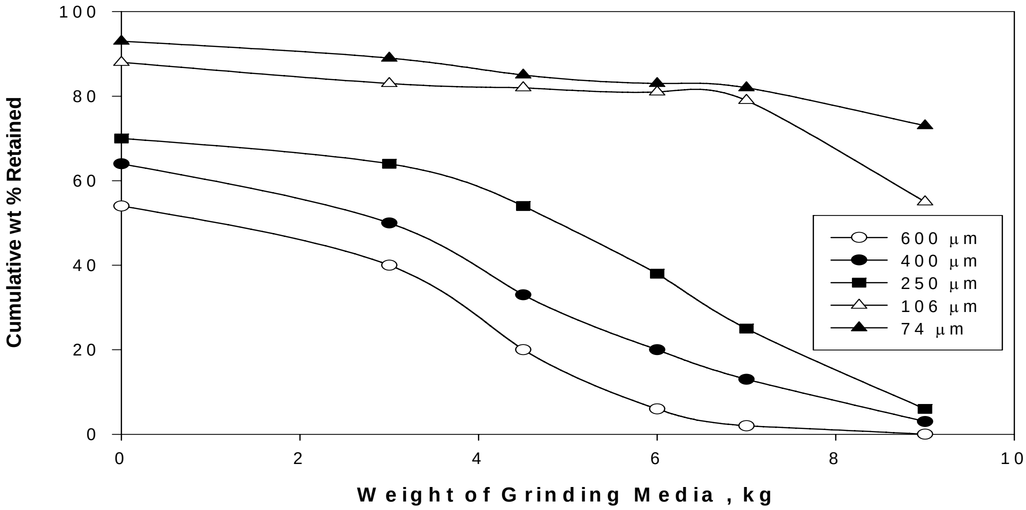

Figure 10. Effect of weight media on the cumulative weight % retained

This lower reduction ratio may be due to the high percentage of filling ratio that reached more than 800% increase of 3kg to 100% filling ratio of voids in case of 9kg. Therefore, the effect of the change of the weight of grinding media at lower weight (3kg) and higher filling void ratio the products of grinding is of wide particles spread ~18, and by increasing the weight the product is of close size as the spread ratio decreased to ~10 as the filling void ratio decreased from 800%, 460%, 201% and 100%. However the new particles created by increasing the weight of grinding, that decreased the filling ratio of void, increased sharply in case of the three coarse particle sizes. This sharp increase in the new particles may be due to that the smaller weight of grinding media hits the coarser particles only which produces medium particles and less amount of finer particles (Figure 11), as the changes in these new particles of finer size did not exceed 10% as the weight increased to 7.5kg and then jumped to 20% and 30% at the weight of grinding media increased to 9kg. On the other hand, the increase in the production of new particles of medium sizes reached more than 50%, and also jumped to more than 60% at 9kg weight of grinding media. The lower percentage of finer sizes may be due to the minimum effect of abrasion zone on ascending of the lower weight of the grinding media, and the effect of this zone may be obvious at higher weight of this grinding media and lower filling voids ratio as clear in the following part.

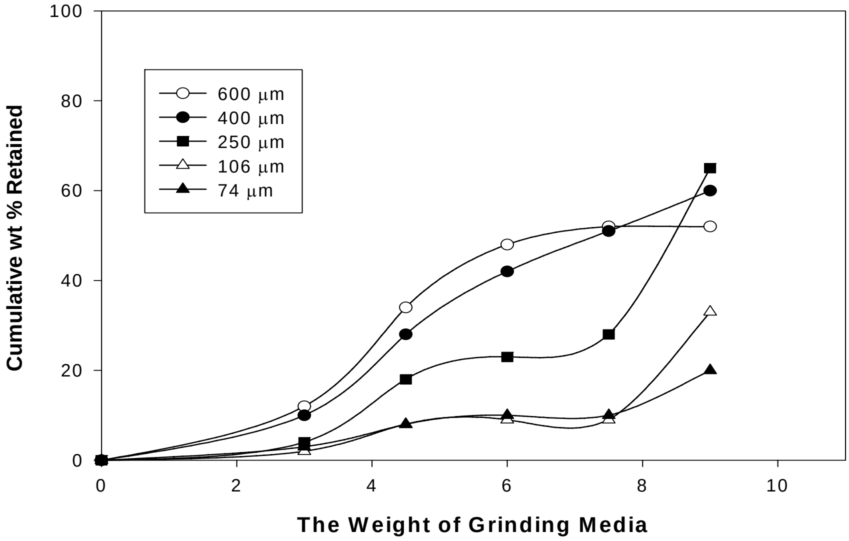

Figure 11. New particles resulted from the change of grinding media weight

3.3. The effect of the filling voids ratio (solid/liquid ratio)

The results of the effect of the change of the solid: liquid ratio (w/w), at constant grinding time(7min) and weight of grinding media (9kg), are shown in Figure 12, from which it is clear that, the ratio produced more finer than the other two ratios, this may be due to the diluted solid and hence the abrasion zone is the most effective and its $D_{90}$is lower than the other ratios i.e. its D_{90} = 0.2mm, and hence the reduction ratio in this solid: liquid ratio is a about 10 times. However, the higher solid ratio produce less finer particles, and the coarser particles ground more due to more probability of compaction of rods with the coarse particles. This effect is clear from Figure 13, where the cumulative weight percent passed increased by increasing the solid: liquid ratio from the three coarse sizes (600µm, 400µm and 250µm), and that finer sizes passed from (106µm and 74µm) decreased by increasing the solid: liquid ratio, may be due to lower effect of abrasion zone as the pulp has higher viscosity because of higher solids content. Therefore, for grinding Albite followed by beneficiation processes, required higher solid: liquid ratio, that minimizes the fine fraction (200 mesh), which is about ~26%, that causes some troubles in the proceeding beneficiation processes. To overcome the problem of fine particles created in the comminution process, another series of tests were carried out at 2min retention time. The results of this group of tests were shown in Figure 14. From which it is also clear that the higher solid / liquid ratio minimizes the fine particles created from grinding from more than ~24% cumulative weigh percent.

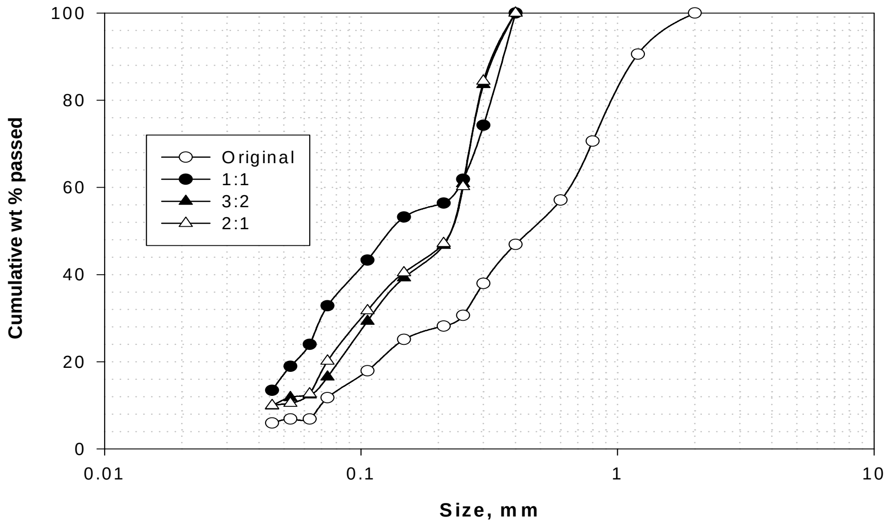

Figure 12. Effect of solid/liquid ratio on the cumulative weight % passed (at 7min grinding time)

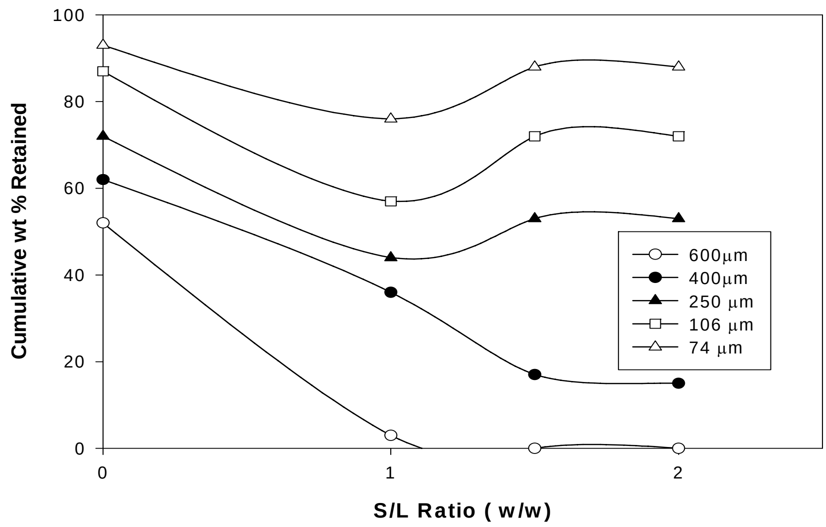

Figure 13. Effect of solid/liquid ratio on the cumulative weight % retained (at 7min grinding time)

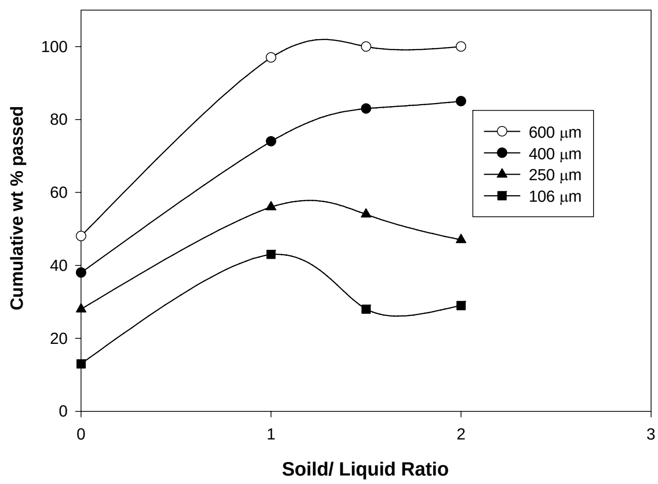

Figure14. Effect of solid/liquid Ratio on the cumulative weight % retained (at 2min grinding time)

4. CONCLUSIONS

For grinding albite ore near the liberation size and minimizing the 74μm fraction using rod mill, concluding remarks are obtained as follow:

- The grinding time (retention time) is limited to 7min, at which maximum new particles of the liberation size (i.e. 250μm) was produced from grinding process. At this retention time (7min) D_{90}/D_{10} is about 7, that means after desliming (removal 74μm), it decreased to about 3 in the final concentrate resulted from the pilot test.
- The action of rod mill was affected on coarser sizes, and the finer sizes were protected by the coarser particles. Therefore the gradual increase in the two finer may be due to the action of abrasion action that occurred in the ascending zone.
- The optimum grinding media is limited to 9kg, at which the increase of new particle medium sizes reach to 60%. The lower percentage of finer sizes may be due to minimum effect of abrasion zone on ascending and lower filling voids ratio.
- The higher solid / liquid ratio minimizes the fine particles may be due to the diluted solid and hence the abrasion zone is the most effect.

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