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Performance Evaluation Studies in Çayeli Grinding Circuit

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ABSTRACT: The aim of the study is to investigate the performance of the grinding circuit of Çayeli Bakır İşletmeleri A.Ş. (ÇBİ) for higher tonnages and also to evaluate effect of hydrocyclone geometry on the performance, after installation of tertiary crusher in the crusher circuit. Seven sampling surveys were undertaken at varying feed rates and cyclone apex and vortex finder diameters. Mass balance studies were performed to calculate flowrates of streams. For all the feed rates examined, the target values for flotation feed, i.e. 70% passing 36(xm and 40% solids by weight, were reached. Although, primary ball discharge became coarser with the increase in feed rate, top size of the product did not change significantly. On the other hand, the performance of 70 mm apex and 130 mm vortex finder combination was better than any other combination.

1 INTRODUCTION

The grinding circuit of ÇBİ flotation plant was originally designed to process 600,000 tpa ROM ore to produce a flotation feed containing 80% -36 micron. The circuit was reached to an annual throughput of 850,000 tons, after modifications during the years.

Further improvement was achieved by the use of single stage classification instead of double stage and annual capacity has reached to 1,000,000 tons. This has also improved control over classification and simplified the operation(Aksam and Mian, 2003).

A tertiary crusher was installed in crushing circuit to provide finer feed to the circuit and also increase the capacity to 1,250,000 tpa.

The aim of the study is to evaluate the performance of the grinding circuit after installation of tertiary crusher and at higher feed rates and varying cyclone apex and vortex finder diameters. These data were also used for the modelling aided optimization of the circuit (Ergün et al, 2005).

For this purpose seven sampling surveys were carried out around the grinding circuit. Four of them were used to evaluate the effect of feed rate on the performance and three sets of samples for the evaluation of the effect of cyclone apex and vortex finder diameter. Further samples were also taken from primary ball discharge which has a limited power.

2 SAMPLING STUDIES AT THE CIRCUIT

Sampling studies were focused to evaluate the effects of feed rate and hydrocyclone apex and vortex finder diameters on the circuit performance. A detailed sampling program has planned by communications with Plant Management. Seven sampling surveys were' carried out in the circuit at different operating conditions which are given in Table 1. Six separate samples were also taken from primary ball mill discharge at various feed rates up to 165 tph *(all the tonnages reported are in dry basis)*.

Table 1. Main operating conditions for the sampling surveys

	Feed rate (tph)	Number of Operating Cyclones	Vortex Finder Diameter(mm)	Apex Diameter (trim)
1	132	4	130	90
2	146	4	130	90
3	151	4	130	90
4	152	5	130	90
5	132	4	140	95
6	132	4	130	95
7	132	4	130	70

Simplified flowsheet and sampling points are shown in Figure 1.

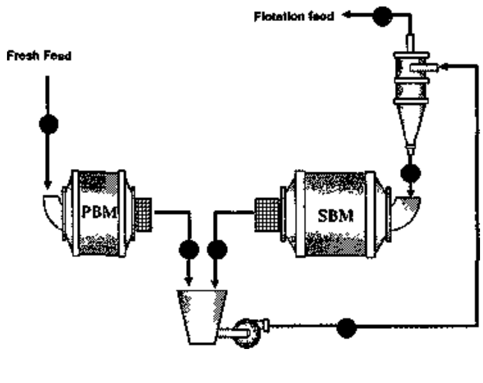


Figure 1. Simplified flowsheet of ÇBİ grinding circuit and sampling points.

Prior to each sampling survey, steady state conditions were verified by examining the values of variables recorded in the control room. Each survey lasted in approximately two hours. During this period, samples were taken from each point with approximately 15-20 minutes intervals and combined in a separate bucket. Due to the physical difficulties, combined stream of hydrocyclone underflows were not sampled. Except Survey 3, samples were taken from all individual cyclone underflows. A stream cutter sampler was used for the hydrocyclone underflows; while a specially designed sampler was used for taking cyclone feed samples from sump. Cyclone feed samples were also taken from overflow pipe of one cyclone which was arranged for this purpose by blocking underflow discharge. The existing sampling system was used for taking samples from the cyclone overflow. For sampling the primary and secondary ball mill products, open channel chutes were intercepted by a shovel to create a well mixed zone at upstream. Then, a ladlelike sampling device with long handle and I liter volume was dipped into the zone and a sample was taken. The feed to circuit was sampled by stopping the conveyor belt and stripping the ore from a length of 1.5-2 m. Separate larger samples were also collected from fresh feed for the determination of Bond work index.

The dimensions and some operating parameters of the ball mills and hydrocyclones are given in Table 3 and 4. The ball loads within the mills were determined by measuring the free height between balls and mill shell during a shut down just before the surveys. The measured ball loads for primary and secondary ball mills were 43% and 35%, respectively. All cyclone dimensions were measured. For the Survey 5-7 cyclone apex and vortex finders were replaced.

Table 3. Design and some operating parameters of the ball mills.

	Primary Ball Mill	Secondary Ball Mill
Mill Outer Diameter (mm)	3200	4400
Mill Length (mm)	4300	7200
Liner Thickness (mm)	100	50
Mill Speed (rpm)	17.4	15.4
Critical Speed, Cs (rpm)	24.8	20 5
%Cs	70.0	75.1
Ball Size(mm)	100-80	40-26
Power (kW)	560	2160

Table 4. Design and some operating parameters of the hydrocyclones

Diameter (mm)	375
Inlet Diameter (mm)	152
VF diameter (mm)	130, 140
VF length (mm)	276
Apex diameter (mm)	70, 90, 95
Cylinder length (mm)	360
Cone angle °	10

3 LABORATORY STUDIES

The samples were first weighed wet. Then, they were dried and weighed again. Solids content of the samples were determined from wet and dry weights. All the samples were sieved from 13.2 mm to 0.85 mm. Approximately 600 grams of samples were taken from -0.85mm by using sample splitters. Then, samples were sieved wet using series of standard sieves down to 0.036 mm. The particle size distribution of -0.036 mm fraction was determined down to 8.8(J.m by a cyclosizer.

Bond grindabilities and work indices of the plant feed samples were determined using standard Bond test for 74 micron test sieve. Bond indices of the feed for Survey 1 and 7 feed samples were 9.70 kWh/t and 9.55 kWh/t, respectively.

4 MASS BALANCING

Using mass flow rate of the fresh feed, size distributions and percent solids, flowrates of each stream were calculated. During mass balancing, errors were distributed according to physical condition at any particular sampling points. For example, larger weighting of error was given to cyclone feed than the cyclone overflow stream.

Convergence limits in al! iterations were chosen as 10^{-5}. Mass balancing of the raw data was accomplished by using JKSimMet software. The measured and adjusted size distributions of the streams around the circuit for each survey are given in Figure 2-8.

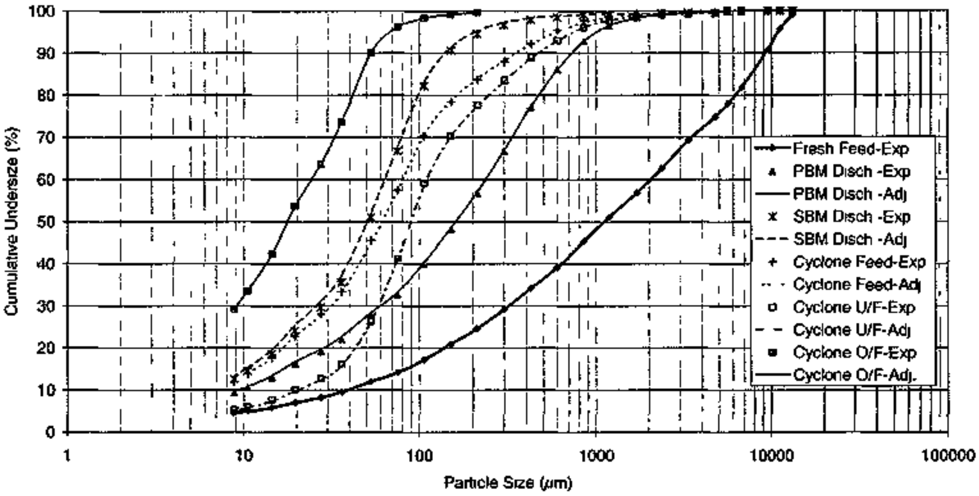


Figure 2. Expenmental and mass balanced size distributions for Survey 1.

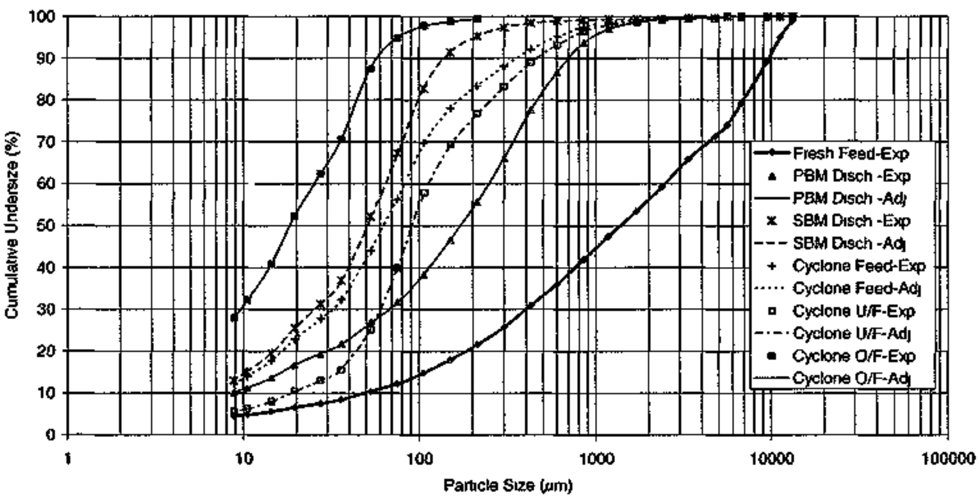


Figure 3. Expenmental and mass balanced size distnbuüons for Survey 2.

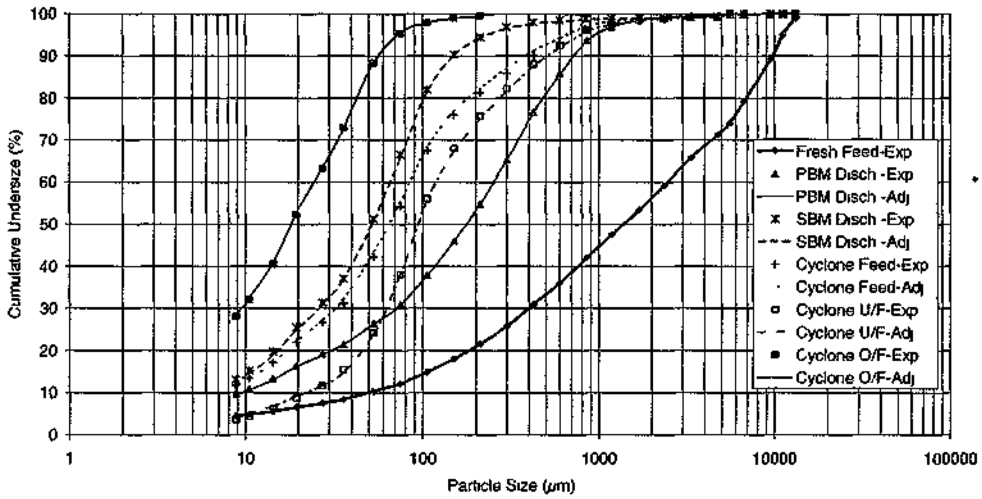


Figure 4 Experimental and mass balanced size distributions for Survey 3

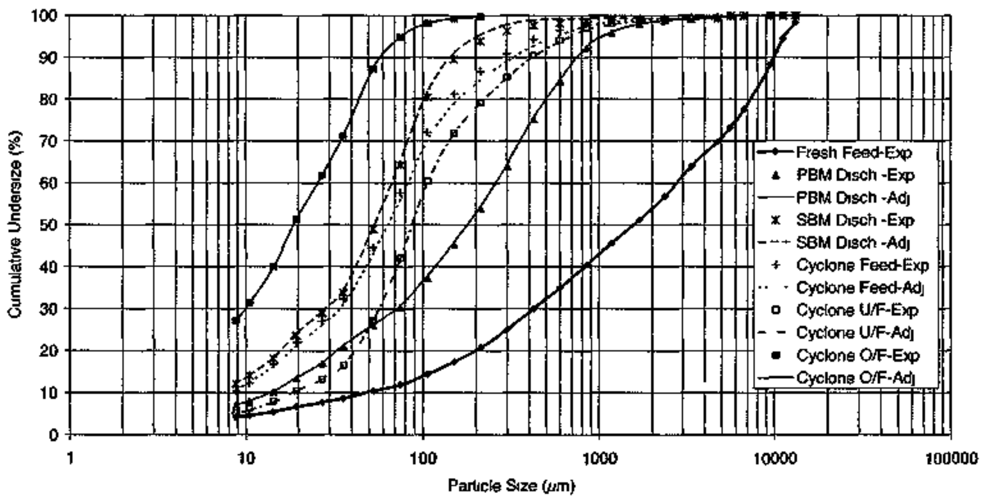


Figure 5 Experimental and mass balanced size distributions for Survey 4

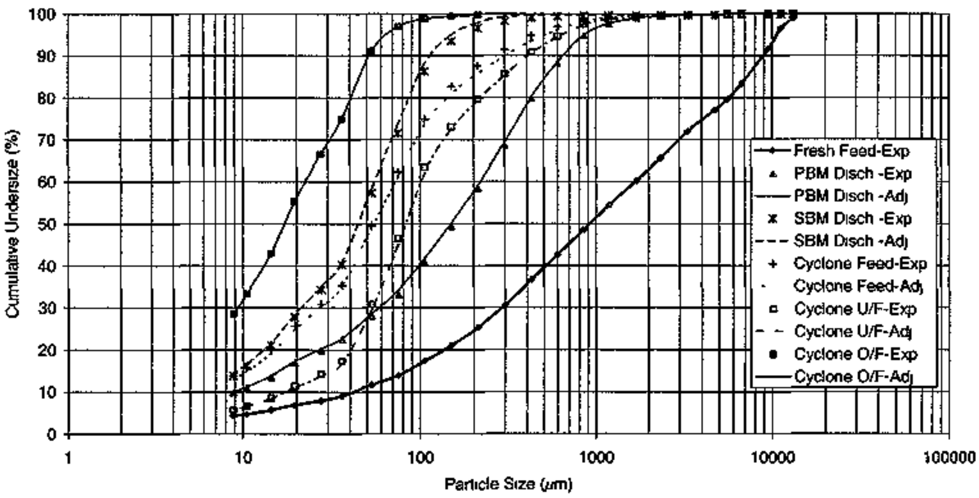


Figure 6 Expenmental and mass balanced size distnbutions for Survey 5

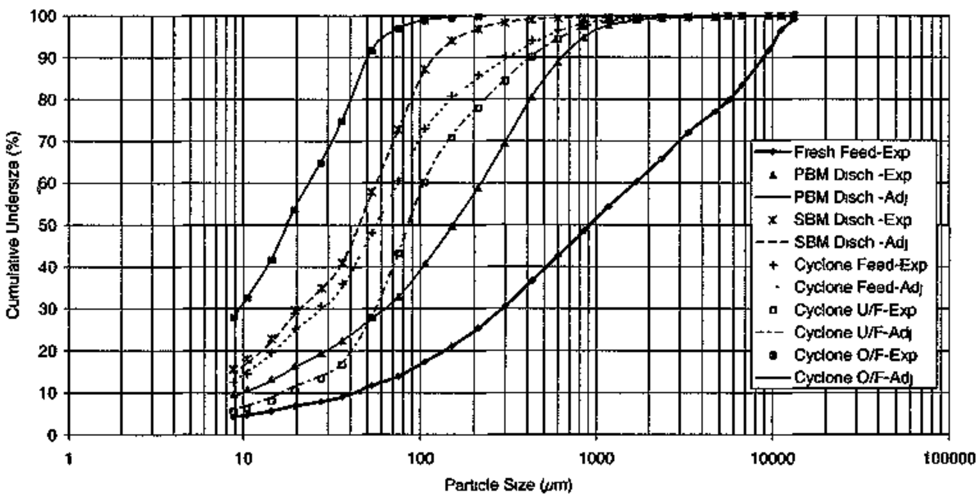


Figure 7. Expenmental and mass balanced size distnbutions for Survey 6

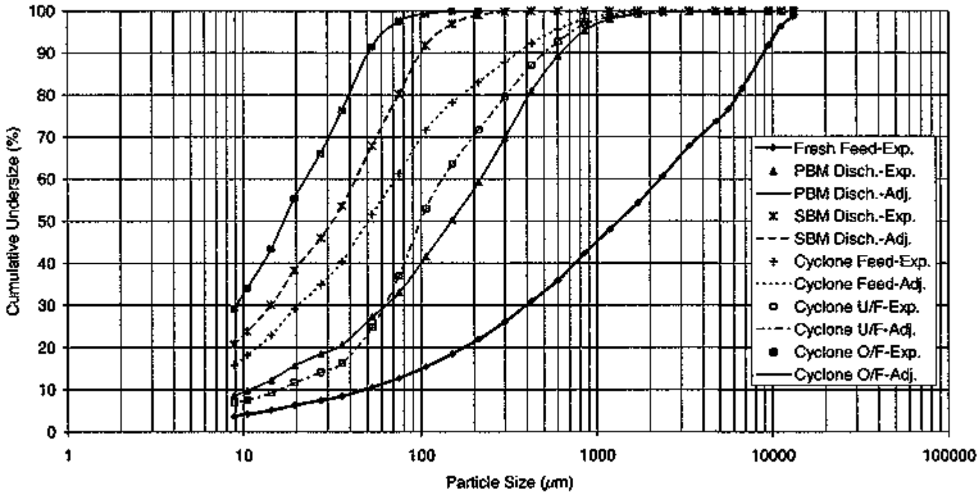


Figure 8. Experimental and mass balanced size distributions for Survey 7.

As can be seen from Figure 2-8, the measured and mass balanced the size distributions of the streams were close to each other showing that sampling studies were performed successfully. The flow rates of the streams calculated after mass balancing are given in Figure 9.

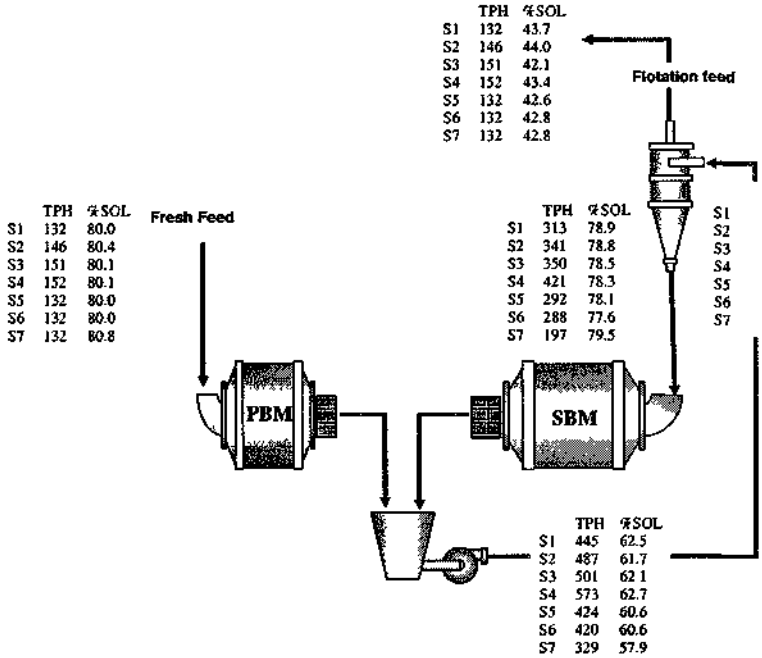


Figure 9. Flow rates of the streams for all surveys and cyclone pressures measured.

5 PERFORMANCE EVALUATION

5.1 Effect of feed rate on the performance

Surveys 1-4 were earned out to evaluate the effect of feed rate on the circuit performance. Four cyclones having 90 mm apex diameter and 130mm vortex finder diameter were used in surveys 1-3. In survey 4, the number of operating cyclones was increased to five.

In terms of flotation feed fineness and % solids, the performance of the circuit did not exhibit any deterioration with the increasing feed rate. For all the feed rates examined, the target values, i.e. 70% passing 36(im (Figure 10) and 40% solids by weight, were reached.

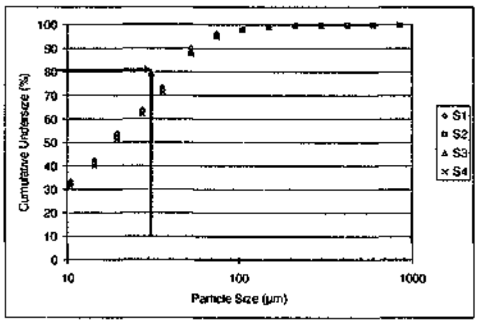


Figure 10. Size distribution of the hydrocyclone overflows for Survey 1-4.

Actual performance curves of the hydrocyclones for Survey 1-4 are given in Figure 11.

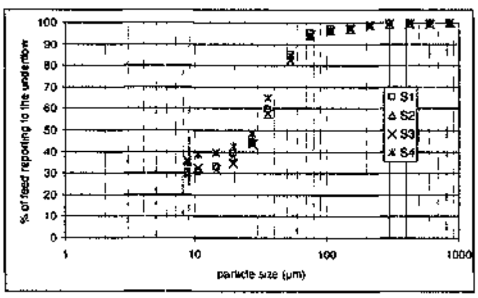
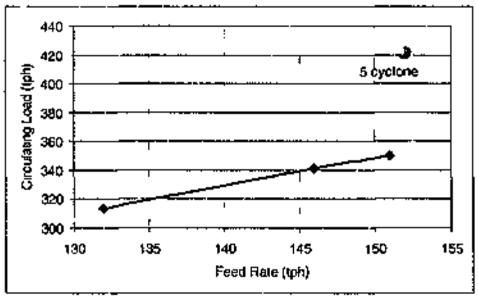


Figure 11. Actual performance curves for the cyclones for the Surveys 1-4.

For the Survey 1-3, the actual performance curvcys were found be very similar. Surveys 4-5 were performed practically at the same flow rate. However, for Survey 5, as the number operating cyclones was increased from four to five, the amount of material going to the underflow increased. This resulted in a higher bypass as shown in Figure 11 and also significant increase in circulating load (Figure 12).



Figuie 12. The effect of feed rate on circulating load tonnage.

As can be seen from Figure 12, an increase in feed rate resulted in a linear increase in die circulating load tonnage when the number of operating cyclones was four. For the five cyclones, a higher increase was observed. The circulating load ratios were in the range of 232-237% for the Survey 1-3 and 276% for Survey 4.

This point was also verified by me operating pressure values. For the four cyclone case, the pressure increased with the increase in cyclone feed volumetric flow rate, however it drastically decreased for five cyclone case. It may be concluded that die four operating cyclones was better than five for the conditions investigated.

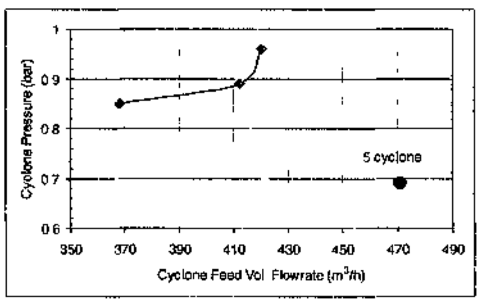


Figure 13. The relationship between cyclone volumetlic feed rate and opeiating pressure.

5.2 Effect of apex and vortex finder diameters

The effect of cyclone apex diamater was evaluated between 70mm and 95mm using the data from Survey 1, 6 and 7. In thses surveys vortex finder dimaters were kept constant as 130 mm. Vortex finder diameter was tested only in two levels of 130 mm and 140 mm for 90 mm and 95 mm apex diameters using the data obtained from Survey 1 and 5. All of these studies were performed at constant feed rate of 132 tph.

Actual performance curves for these surveys are presented in Figure 14. Except for Survey 7, the cyclone performance did not change significantly. However, in Survey 7 the bypass of the separator significantly reduced. Actual d_{50} of the cyclones in Survey 7 was about 38 |im, whereas it was about 30 |im for the other surveys.

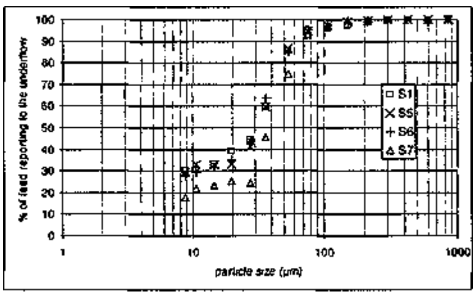


Figure 14. Actual performance curves for the cyclones for the Surveys 1 and 5-7.

Since 70 mm apex in Survey 7 was the minimum apex diameters tested, minimum water recovery to the underflow was expected. The percent solids of the cyclone underflow 79.5 % and was the highest, as expected.

As the apex diameter decreased, the size distribution of cyclone underflow became coarser. The size distributions of cyclone underflow streams for 90 mm, 95 mm and 70 mm apexes are given in Figure 15.

For the range studied, the performance of 70 mm apex was better than the others. The product was the finest among all surveys. The circulating load tonnage was 197 tph and circulating load ratio was 149%. Operating pressure for the cyclones was 0.53 bar. Although actual d_{50} of the cyclones is greater than the other, the tonnage going to secondary ball mill significantly reduced. Therefore, it was functioning much better. P80 of secondary ball mill discharge was 74 um, while for the other surveys at the same feed rate varied between 98 fini and 86 (Jin. In other words, -36um was about 54% for 70 mm apex, while varied between 37% and 41% for the other apex diameters.

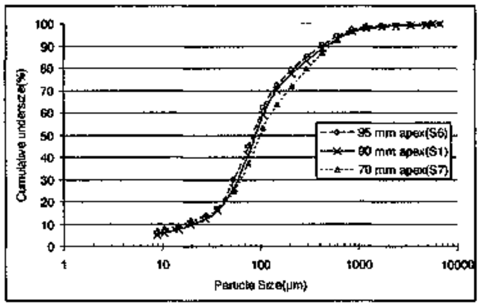


Figure 15. Size distribution of the hydrocyclone underflows for different apex diameters.

Changing vortex finder diameter from 130mm to 140 mm did not exhibit a discernible difference probably due to the differences in apex diameters.

Finally, for the all the surveys (1-7), reduced performance curve of the hydrocyclone is presented in Figure 16.

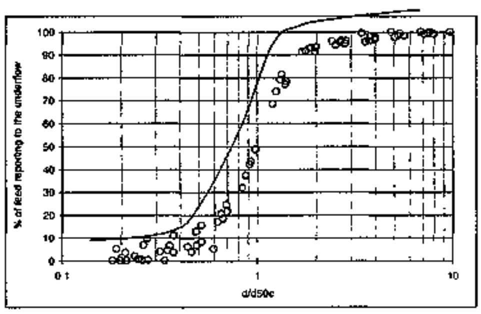


Figure 16. The reduced performance curve for the hydrocyclone

5.3 Effect of feed rate on primary ball mill performance

One of the constrain to increase the capacity of the circuit seemed to be the performance of primary ball mill. Therefore, apart from planned sampling .surveys, separate samples were also taken from primary ball mill discharge to evaluate the performance of it at higher tonnages. Size distributions of primary ball mill discharge samples at various feed rates are shown in Figure 17

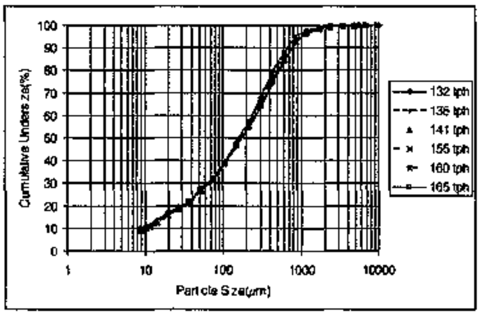


Figure 17 The size distributions of pnmary ball null discharge at different feed rates

As can be seen from the figure, an increase in feed rate resulted in a coarser product However, the top size of the product did not change significantly

For a better demonstration, Figure 18 were drawn by modifying the Figure 17

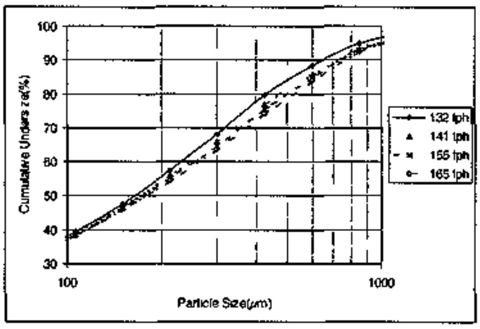


Figure 18 The effect of feed rate on primary ball mill performance (scales are adjusted)

6 DISCUSSION

Performance of the ÇBI grinding circuit was evaluated by the data obtained from detailed sampling surveys

Since all the information extracted from the surveys maximum care musi be taken for representative sampling Although some general rules available (Napier-Munn et al, 1996), sampling procedures for each plant and particular sampling point must be developed

Mass balancing studies provide the evaluation of the sampling procedures as well as calculation of flow rates and adjusted size distributions Adjustments in the measurements are the indication of the quality of the sampling procedures Mass balancing algorithms can not adjust erroneous data, however, help to identify where sampling method is not appropriate With this respect, as shown in Figure 2 8, sampling in this study were performed succesfully

After mass balancing, the quantitative picture of circuit performance for each survey was obtained The results showed that the capacity of the circuit could be increased to 150 tph and the performance could be improved by optimizing the cyclone parameters However, it is extremely difficult to optimize the circuit by plant scale tests, due to the number of variables affecting the performance (Lynch, 1977, Napier Munn et al, 1996) Simulation ıs a very useful tool for optimization of the circuits by considering all the variables involved simultaneously In an earlier study m ÇBI grinding circuit, the success of modelling and simulation has proven during conversion of double stage classification to single stage (Ergun et al, 2000, 2002, Aksanı and Mian, 2003)

The studies for the optimization of the circuit will be presented m another study (Ergun et al, 2005)

7 CONCLUSIONS

The performance of the ÇBI grinding circuit was evaluated by the data obtained from several sampling surveys performed after installation of a tertiary crusher in crushing circuit

The ÇBI grinding circuit can be operated at 150 tph without deterioration in flotation feed fineness and % solids This would also provide 15% decrease in specific energy consumption of the circuit

The performance of the circuit could be improved by optimizing cyclone paramaters

The primary ball mill discharge became coarser with increasing feed rate However, the top size of the product did not change

Acknowlegment

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