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Control of Comminution Circuit for Efficient Froth Flotation

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ABSTRACT

Efficiency of separation in the froth flotation circuit is very much dependant on the efficiency of size reduction and size separation in the preceeding comminution and classification circuit. A coarser grinding product than desired causes loss of grade or recovery due to inadequate liberation where as with over grinding there is an increase in slime loss. This paper ennumerates the factors that affect the performance of the grinding circuit and the steps that should be taken for its efficient operation. Once the grinding circuit is commisioned its performance is dependant mainly on the operation and control of the classifier. In case of the mechanical classifiers very effective control can be obtained by suitably varying the wash water flow rate and the weir height. In case of the cyclone classifiers the control is some what difficult.

Key Words : Comminution circuit, Control froth flotation, Operating parameters, Efficiency.

INTRODUCTION

The froth flotation process is extremely sensitive to the particle size. Ideally the particles should be just small enough to ensure liberation of the ore from the gangue and no smaller. In some rare cases of relatively high grade ore deposits some what acceptable liberation may take place at a size too large (+1 mm) to float in the froth flotation, process. In such cases the ore should be ground to about -0.3 mm to ensure flotation as the flotation rate is observed to decrease rapidly with the increase in particle size. However in most cases complete liberation is never achieved and an acceptable degree of liberation mostly requires grinding to a size finer than 75 microns or even 37 microns.

Grinding to such a fine size can result in the production of substantial quantity of slimes resulting in slme loss. This is often observed in lead ore grinding circuits. A thumb rule is that the optimum size of grind is the size at which the loss of recovery due to lack of liberation is equal to slime loss. A high circulating load in the grinding circuit generally gives a closer sized product. For grinding circuits preceeding froth flotation circuits the circulating load is typically higher than 200%.

PULP DENSITY

Next to the size of grind, the most important parameter affecting the design, operation and control of the grinding circuits is the pulp density to be maintened in the classifier and hence the pulp densities that are possible in the grinding mill and the flotation (particularly rougher) cells. It is generally (though not universally) found that higher pulp density (upto 90 % solids by weight) in the mill gives better grind.

In the rougher cells, for a specified solid flow rate and residence time, to keep the total cell volume required to a minimum the pulp density should be high, upto 45 % solids by weight.

But finer the grind desired, the lower is the pulp desnity required in the classifier. Some suggested pulp densities are shown in Table 1.

Table 1 : Suggested pulp densities in classifers

Separation size, mm	1.0	0.5	0.3	0.15	0.1
% Solids by weight	45	35	25	25	15

With high circulating loads it is difficult, if not impossible, to maintain the higher pulp densities desired in the grinding mill and rougher flotation cells. An illustrative examples are given here.

Example 1 :

In a grinding circuit with 200% circulating load the pulp density of classifier underflow is 75% solids by weight the pulp density desired in the mill is 90% solids by weight and in the rougher cells 35% solids by weight; where as in the mechanical classifier following the grinding mill the pulp density can not exceed 35% solids by weight.

Assuming solid flow from the crushing circuit to be 100 tph,

the solid flow to the classifier = 100+200 = 300 tph

total water in the classifier = (300/35)x65 cmph = 557.1 cmph

Water going to the mill with the coarse product = (200/75)x25
= 66.7 cmph

Pulp density inside the mill = (200+100)/(200+100+66.7)
= 81.8% solids by weight
(lower than the desired 90%)

Water going to the rougher flotation circuit = 557.1-66.7
= 490.4 cmph

Pulp density in the rougher cell = 100/(100+490.4) = 16.9% (much lower than the desired 35%)

If the circulating load is higher the pulp densities in the mill as well as the rougher cells would be much lower. In a few cases dewatering cyclones are used to remove part of the water from the final ground product before it is sent to the flotation circuit.

Cyclone classifiers can operate at a comparatively higher pulp density than the mechanical classifiers, particularly when dealing with separation sizes like 75 microns or smaller. However the pulp density of the underflow is generally lower than that of the coarse product and makes it even more difficult to maintain a high pulp density in the mill as shown in example 2.

Example 2 :

If in example 1, a cyclone replaces the mechanical classifier, the pulp density in the cyclone would be say 45% solids by wt. and the water split to the undeflow would be about 15%.

With 200 % circulating load water entering the cyclone ·
= (100+200)x55/45 = 366.7 cmph

Water going to the mill with underflow = 0.2x366.7 = 73.4 cmph

Pulp density in the mill = (100+200)/(100+200+73.4) = 80.34% solids by weight
(A little lower than earlier 81.8%)

Water going to the rougher cells = 366.7-73.4 = 293.3 cmph

Pulp density in the rougher cell = 100/(100+293.3) = 25.4%
(Higher than earlier 16.9% but still lower than 35% desired)

If the desired sizing can be achieved with a very small circulating load the control of pulp densities in the mill and the rougher cells is some what easier. To get closer sizing in the mill itself and thus to reduce the circulating load, different designs of mills like tube mills, Hardinge mills etc. have been tried but all of them result in a higher energy consumption per unit mass of ore ground.

Any increase in the energy consumption per unit mass of ore ground in the comminution circuit is not desirable, as in almost all beneficition plants based on froth flotation atleast 50% of the total energy requirement of the plant is consumed in the comminution process. Thus ball mills with high circulating loads, in spite of their other draw backs remain the most energy efficient grinding systems to prepare the feed for the flotation circuit.

However the difficulty in achieving the high pulp densities desired in the mills and the flotation cells, and therefore the additional capacity required, must be taken into account in the design stage of the plant.

OPERATION PARAMETERS

In an operating grinding circuit the parameters which can be controlled by the operator are :

1. In case of a mechanical classifier water flow rate to the classifier and in case of a cyclone the water flow rate to the sump.
2. Water flow rate to the grinding mill.
3. In case of a mechanical classifier the weir height. There is no corresponding control parameter available in case of the cyclone. The underflow nozzle size can be changed only at the time of a shut down atleast for a small period.
4. Feed rate to the mill.
5. Speed of the mill.

In operation, the control parameters should be tried in the order given above. For example, the water flow rate to the classifier or the cyclone feed sump should be continuously noted and readily altered according to the requirement. In contrast the mill speed should be altered only if all other measures fail to achieve the desired result. In most of the plants there may not be any provision to alter the mill speed in operation.

Control of the grinding circuit is based mainly on the report from the froth flotation section. Traditionally the vanning plaque used by the flotation circuit operator gave a fairly good indication of the size of the grind as well as a rough estimate of the grades.

Modern online analysers have made the operators job much easier with respect to determining the grades (assay values) of the feed, concentrate and tailing of each stage of the flotation circuit, but the good old vanning plaque can still be handy in supplimenting the information from the online anlysers.

It is a pity that the vanning plaque is not very commonly seen in the modern beneficiation plants of India. Revival of its use can substantially help in the control of the comminution as well as froth flotation circuit.

WASH WATER RATE

The water added in the classifier, often referred to as the wash water, is the most important control parameter, as it is the simplest device of varying the separation size in the classifier and hence the product size of the grinding circuit. If the product of the grinding mill is finer than desired, then the wash water rate has to be marginally reduced and the effect observed for a few minutes. Similarly to reduce the separation size the wash water rate should be marginally increased.

Generally marginally increasing the pulp density increases the separation size in the classifier and diluting the pulp decreases the separation size.

Here it is important to note that decreasing the separation size in the classifier increases the load on the grinding mill and so the rate of the circulating load should also be observed whenever the wash water rate is changed.

In case of a cyclone classifier the rate of water addition in the sump feeding the cyclone feed pump should be continuously observed and varied according to the requirement to keep the pulp level in the sump constant. Fluctuations in the pulp level in the sump can adversely affect the efficiency of separation in the cyclone.

The discharge of the cyclone underflow should be continually observed to ensure that it is of the proper type (generally an umbrella shaped discharge is desired as it helps the formation of the air core).

WATER ADDITION IN THE GRINDING MILL

When the circulating load is very low, some water may have to be added in the grinding mill to maintain the pulp density.

However as illustrated in examples 1 and 2, the pulp density in the grinding mill is often lower than the desired value and there is no scope of addition of water in the grinding mill.

In any case the provision for addition of water in the grinding mill is essential to guard against the possibility of choking of the discharge.

Depending on the nature of the feed and the circulating load, at times the discharge of the ball mill may get choked. This is indicated by the continued reduction in the discharge rate from the mill.

In such case often there is a tendency to increase the water flow rate inside the ball mill to flush out the choking amterial. In many cases it works; but at times it may lead to the sudden flow of a large quantity of material into the classifier.

In stead of adding more water it is better to reduce the feed rate or even altogether stop it till the discharge is cleared.

WEIR HEIGHT

The height of the overflow (undersize) discharge weir of a mechanical classifier should be altered when variation in the wash water addition rate does not bring about the desired change in the separation size.

Usually raising the weir height results in a smaller size of separation by increasing the classifier pool area. Similarly lowering the weir height results in increasing the separation size. However lowering the weir height and thus reducing the pool area generally results in less efficient separation (as measured by the Tromp curve).

In case of a cyclone a similar effect on the separation size can be obtained by changing the nozzle that determines the underflow diameter. However in case of a cyclone any change in the underflow diameter has a greater detrimental effect on the efficiency of separation than a mechanical classifier.

FEED RATE

When the grinding circuit is in a steady state operation any change in the separation size creates an instability that has a cumulative effect on the circulating load. Reducing the separation size results in increase in circulating load and the total load in the mill. It may ultimately result in choking the mill.

Therefore whenever the separation size is reduced the rate of discharge should be closely watched. If it continues to increase even after a lapse of some time the feed rate should be marginally decreased.

Similarly if the separation size is increased the circulating load may come down to below the acceptable limit resulting in larger proportion of slimes. To avoid that the feed rate may have to be increased to stabilise the circulating load. Any such variation in the feed rate must be immediately reported to the flotation section so that corrective action can be taken there.

CIRCUIT SHUT DOWN

Mechanical classifiers are generally not designed to start under the load of the settled sand when the plant is started after a shut down. Therefore while shutting down the grinding circuit it is neccessary that first the mill should be stopped and all the sand in the classifier should be allowed to drain out.

The classifier should be stopped only when there is no appreciable quantity of sand left. Most classifiers have an arrangement to lift up the rake after the classifier is stopped. In such cases the rake should be lifted up after it is stopped.

If the plant has been stopped due to a power cut, care should be taken to avoid the overloading of the rake at the time of starting. Before starting the rake sufficient wash water flow should be allowed to flush out most of the sand.

Generally the hold up mineral need not be flushed out of the mill for routine week end shut downs. Usually its presence or absence makes very little difference to the starting torque. However before shut downs for changing the liners and ball charge it is better to cut off the feed well before stopping the mill to allow most of the mineral to flow out.

The control strategies described so far can be effective only if the grinding mill, its liners, grinding balls, drive, couplings etc. are maintained properly. Therefore the sound of the mill, the current drawn by the drive motor, the mill speed etc. must be continuously monitored in operation. The ammeter reading showing the current drawn is a good indicator of the reduction of the ball charge due to wear and tear, and therefore the need of topping it up.

Similarly the ball size distribution, the state of the liner, drive, couplings etc. should be periodically checked and rectified.

CONCLUSION

In the olden days the shift engineer had to depend mainly on his own instinctive judgement and experience for adopting a control startegy as the results of the sieve analysis and assays of the samples were available only after a few hours and served the purpose of only a post mortem.

In the modern plants the flow meters, online analysers, density gauges etc. give quick indications of the state of operation. These devices suitably linked to the control room can also give audible warning when any of the monitored parameters is beyond the acceptable range and enable the shift engineer to take immediate corrective steps to maintain the desired size distribution of the ground ore.