Jhamarkotra phosphate ore processing plant

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ABSTRACT: Low grade phosphate ore of Jhamarkotra that analyses 16.5% P_2O_5 is upgraded to 34% P_2O_5 by a two stage flotation process after size reducing the ore to 90% passing through 200mesh using conventional equipment such as jaw and cone crushers followed by ball mills. Reengineering the flotation circuit reduced the powerconsumptionfrom55 kWh per metric ton of ore treated to 50 kWh. Incorporation of roller press in the grinding circuit resulted into further reduction of power consumption to 32 kWh per metric ton of ore treated.

INTRODUCTION

Beneficiation of phosphate ores containing carbonate gangue minerals such as calcite and dolomite is one of the toughest problems before mineral process engineers, whereas phosphate ores with siliceous gangue (Florida, Senegal, Matoon ores) can be processed [1] by direct flotation of apatite minerals with soap collectors after desliming the ore(to remove clay, chert etc.) before milling. However, laboratory/pilot stage techniques to separate apatite, carbonate minerals are known. These techniques [2] involve reverse flotation carrying carbonate minerals into the froth product using soap collectors while depressing apatite minerals either by phosphoric acid or by fluosilisic acid and the phosphate concentrate is recovered as chamber product (tailing).

Discussing conventional crushing (e.g. jaw and cone crushers) and grinding (ball mills for example) Gaudin questions [3] "why comminuting efficiencies of apparently effective machines should be so low". The efficiency of grinding (Ball mill) may be 10% or still low. It is reported [4] that 50% of the costs incurred in base metal concentrators is on grinding. Prof. K. Schonert designed a size reduction equipment (commercial machines are popularly known as roller presses or High Pressure Grinding Rolls) which is based on the principle of "crushing a mineral particle between other mineral particles instead of grinding elements". This is achieved by choke feeding the roller press that has two rolls of which one is fixed and the other is sliding. Both rolls are driven by separate motors, and comminution pressure is hydraulically applied to the sliding roll. These machines are highly energy efficient and are very successful in cement industry. The success of these machines in mineral processing industry (hard rock) is very limited mainly due to the wear problems of the grinding surfaces [5].

THE JHAMARKOTRA PROCESS

Jhamarkotra ore is having 13 to 18% P_2O_5, 10-12% MgO and 4-6% SiO_2.The major minerals are sedimentary crypto crystalline apatite, dolomite and quartz along with some minor quantities of oligoclase, sillimanite etc. Jhamarkotra deposit contains 40 million tons of such low-grade ores. The process involves size reduction of the ore lumps through crushing and grinding to 90% passing through 74 microns followed by bulk flotation of apatite and carbonate minerals leaving siliceous gangue into the tailing. The bulk concentrate is taken to the second stage flotation where acidic pH (5.0 to 5.5) is maintained using sulphuric acid (11 to 12 kg per ton of ore) and phosphoric acid (6 to 7 kg per ton of ore) is used to depress apatite minerals while floating dolomite with oleate (1.2 kg per ton of ore). Alfa olefin sulfonate (150 to 200 grams per ton of ore) is used along with oleate. This process is successful with dolomite gangue while excessive (>6%) presence of calcite in the ore upsets the process by reducing the concentrate grade to below 34% P_2O_5. It was found [6] that soaps of mixed fatty acids having the titre point in the range 22-26^{o} C and with an iodine value between 88-93 and having a total fatty matter between 60-65 are very efficient. It was proved [6] by carrying out bench scale experiments that the soaps of saturated fatty acids (e.g. stearic acid) are more efficient than the soaps of unsaturated (e.g. oleic) fatty acids, as flotation collectors, particularly in acidic circuits. However it is required to prepare hot solution [7] if soap of saturated fatty is to be used.

PLANT LAYOUT -1500 TPD

Run of mine analyzing 17.5% P_2O_5 in the size < 1000 mm is fed into a coarse ore bin (COB). The material is drawn from the COB through an apron feeder (max. capacity 345 mtph) and fed into a double toggle jaw crusher (1500 X 1200 mm driven by 190 kW motor). The crusher product (200 mm max) is taken to a buffer stock pile. The material from the buffer stock pile is drawn through a reciprocating feeder located in a tunnel below the stockpile through a conveyor that feeds a double deck screen of 152.4 mm X 406.4 mm driven by 30kW motor in closed circuit with a short head cone crusher (1750mm, driven by 200 kW motor) of HEC. The secondary crusher product (60 mm max) can be either taken to stock piles where stacking and reclaiming arrangements are made or to the tertiary short head cone crusher (1750 mm, driven by 200kW motor) directly, which is also in closed circuit with a double deck screen of 203.2 mm X 508 mm, driven by 30 kW motor. The final crushed product is maximum 12.5 mm, which is fed to fine ore bins having a total capacity of 3000 mt. The material from the fine ore bins is fed to two ball mills (3.3meters dia and 4.2 meters length), each driven by a motor of 600 kW. Each mill can be fed at the rate of 32 to 36 metric tons per hour (mtph). The mills are rubber lined and are in closed circuit (Figure 1) with hydro cyclones (three D-10 cyclones in each mill operating at a time). The mill discharge is pumped to the cyclones through a variable speed pump (75kW). The cyclone overflow is classified in two sets(one each for a mill) of secondary cyclones. The secondary cyclone overflow goes to bulk thickeners and the underflow is taken to bulk flotation (apatite and dolomite) circuit layed in two streams each stream having 6 cells of $9m^3$. While bulk circuit tails are discarded, the bulk concentrate is fed to the bulk thickeners. The bulk thickener underflow is drawn by horizontal pumps with variable speed motors in measured quantities at the rate of 24 to 28 mtph dry solids basis and fed into a stream consisting of two flotation lines. The plant has two bulk thickeners that feed four flotation lines at the rate of 12 mtph to 14 mtph (each line) as controlled by PLC. After the addition of phosphoric acid, the pH of the pulp is adjusted to 5 to 5.5 by adding sulphuric acid. Each flotation line in the acid circuit is having 12 flotation cells of 9 m^3. The pulp density is maintained at 1.3 before it enters the flotation circuit and soap solution is added at 3 points in each line to float dolomite. The dolomite rougher concentrate is cleaned twice. The first cleaner has 3 cells of 9 m^3 and the second cleaner has 3 cells of 9m3. The phosphate concentrate is collected as chamber product (tail) of the rougher cells of the acid circuit. The concentrate is thickened and filtered to get a phosphate concentrate cake at18% ±1% moisture. The concentrate is air dried to get moisture content <12% and is dispatched.

REENGINEERING

Flotation

The flotation circuits of the Jhamarkotra plant were constructed using Denver-Sala flotation cells (AS-9) of 9 m^3 volume which were fitted with an impeller drive motor of 18.5 kW. Plant engineers carried out re-engineering of the flotation cells such that a single motor of 18.5 kW drives two cells of 9 m^3 each. This brought down kW/m^3 from 2.05 to 1.02. At the same time by improving the airflow into the cells, the capacity of one line in the acid flotation circuit has been increased from 14 mtph to 32 mtph. This has resulted into reduction in the power consumption from 55 kWh per metric ton of ore processed to 50kWh per metric ton. These developments raise several questions [8,9] on our current knowledge about flotation kinetics and scale up of flotation circuits.

Grinding

The average Bond's Work Index (BWI) of Jhamarkotra ore is 7 kWh per short ton. KHD Humboldt Wedag (Germany), tested the ore on a pilot size roller press having stud lining, pressing the material at 5N/mm2. After removing 125 micron size material, the coarse fraction is crushed to -3 mm size and BWI of this material is observed to be at 5.73 kWh per short ton. These tests also showed specific power consumption by the roller press to be 1.9 kWh per metric ton. After stabilization of the plant throughput and the process to give a consistent quality of phosphate concentrate at +34% P2O5, efforts were made to improve the grinding circuit. Roller Press of 120 cm (diameter) and 63 cm (width), driven by 350 kW motors each manufactured by KHD Humboldt Wedag) is incorporated in the grinding circuit (figure 2) to work in tandem with one of the existing ball mills (600 kW). The roller press discharge cake is wet screened over a screen (of 3.6 meters width and 6 meters long) having slots of 1.8 mm width and 20 mm long.

The wet screen underflow is fed to 3 cyclones of 254 mm diameter and its over flow is taken to secondary cyclones, while the underflow is fed to the ball mill which is operating in closed circuit with 8 cyclones of 254 mm diameter. Ball mill cyclone overflow is also taken to the secondary cyclones. The overflow of secondary cyclones goes to the acid circuit and the underflow to bulk flotation. The roller press can take a feed size up to 30 mm, though it is presently being fed with -25 mm ore, by making necessary changes in the tertiary crusher set and the screen operating in closed circuit with it. The introduction of roller press in the grinding circuit(RPBM) has reduced the overall power consumption from 50 kWh per ton of ore treated to around 32 kWh, while giving, a fresh feed @ 120 mtph, and with an estimated recirculation load of 168 mtph.The RPBM circuit became operational since 27.3.2003.

CLOSING REMARKS

The Jhamarkotra process is well established to deal with low grade phosphate ores that contain dolomite gangue with minor quantities of silicate minerals.Separation of apatite and calcite is still a problem, though the presence of calcite in Jhamarkotra ore is limited to few blocks in the deposit. The available literature suggests a scale up factor of 2 to 2.9 for converting flotation time determined in bench scale experiments to residence time of industrial size flotation circuits whereas in actual practice [9] the scale up factor may be as high as 4.5 to 6. This is largely because of the difference in the rate of airflow per unit volume of the flotation cell and the size distribution of air bubbles in the batch flotation cell and the industrial cell. The least monitored parameter in an operating flotation plant is the rate of air flow, despite the fact that the kinetics of flotation and the capacity of a flotation cell are dependent on the rate of airflow per unit volume of the flotation cell. The bulk thickeners are removed from the reengineered (3000 TPD) flotation circuit without any adverse effect. The retrofitting of the roller press in the grinding circuit of the Jhamarkotra concentrator has drastically reduced the power consumption by 18 kWh per ton of ore treated while operating the plant @ 120 mtph of fresh feed. The ore forms an autogenous wear layer around the rolls because of the stud lining which prevents the wear of the rolls.

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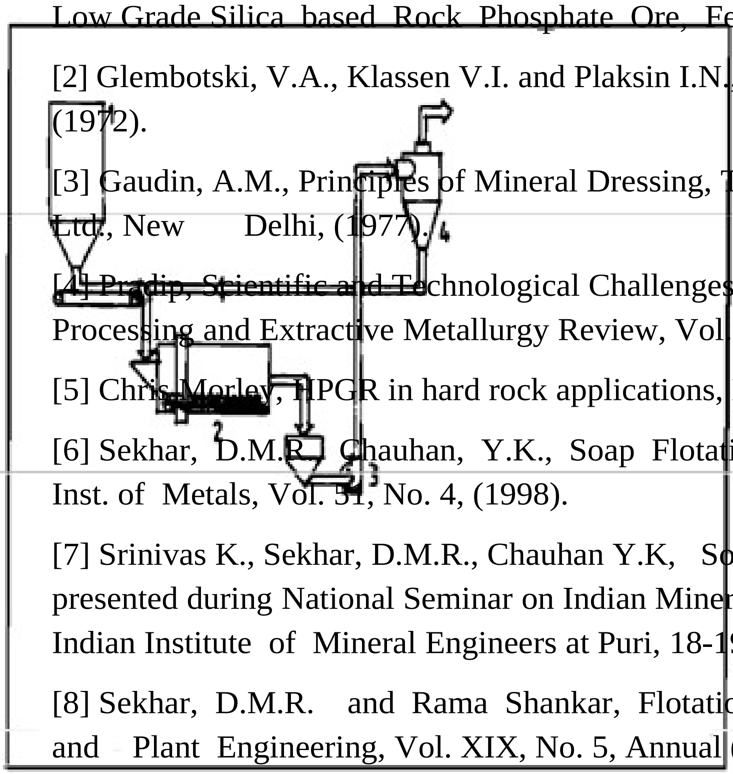

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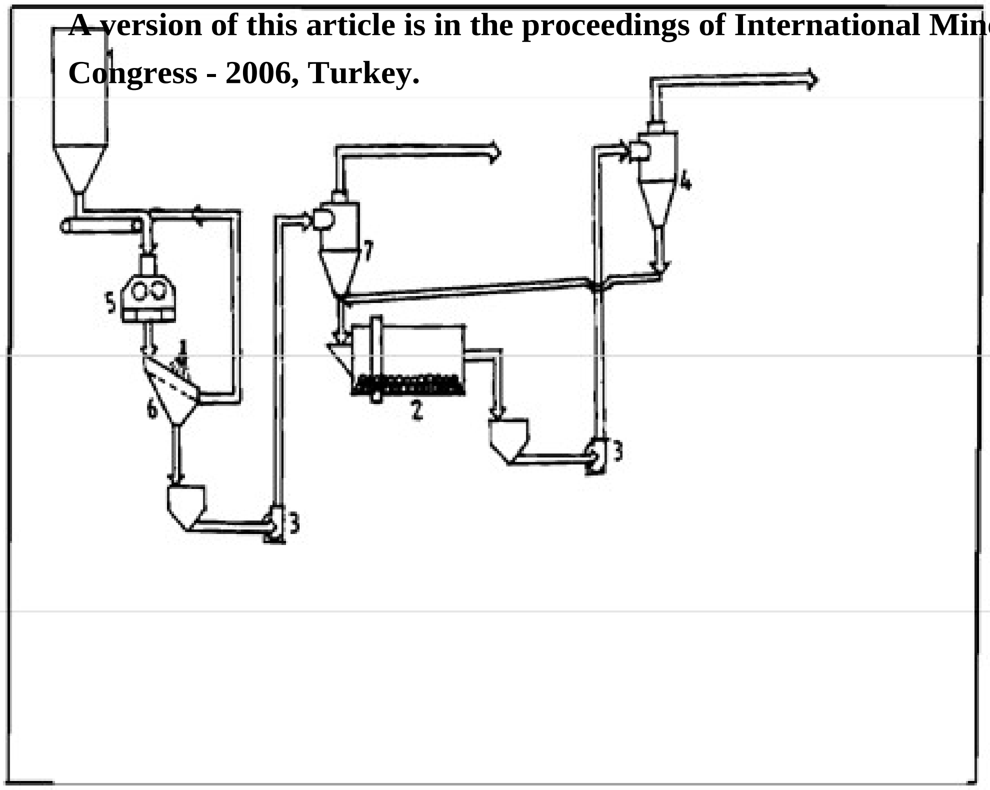

tph 32

tph 128

tph 32

1) Ore Bin
2) Ball Mill , 600 Kw; Bm
3) Bm Discharge Pump
4) Bm, Hydrocyclones
5) Roller Press (350+ 350) = 700 Kw, Rp
6) Wet Screen
7) Rp, Hydrocyclones

Figure 1. 750 tpd ball mill circuit

tph 71

tph 54

tph 175

tph 125

tph 71

Figure 2. 3000 tpd roller press ball mill circuit