Rhodax inertial cone grinder

by J.C. Taylor*

Synopsis

The Rhodax inertial cone grinder, designed by France's FCB Group Fives, is the result of three years, theoretical and mechanical research in the field of compression grinding by the research staff of FCB's CRM minerals research centre. A number of potential uses have been assessed and will be discussed in the paper.

The crusher is an inertial grinder that works on the pressurized bed fragmentation principle. The fragmentation force is caused by the rotation of unbalanced masses rather than by an eccentric mass, as is the case in a conventional crusher. This makes it possible to achieve very high reduction ratios. By controlling the speed of rotation of the unbalanced masses, the grinding force can be modified, thus changing the product size distribution.

The paper describes the machine layout, operating principles, control parameters and will briefly describe the results obtained on reef, waste and ROM reject pebbles. Some comparisons are made with conventional crushing.

Introduction

The Rhodax is the result of three years of theoretical, mechanical and particle research by the research centre at France's FCB Group Fives. The unit is loosely designed around the Russian machine called the KID. The Rhodax makes use of similar fragmentation principles to the KID but with a very different mechanical construction. The differences in design are such that the Rhodax has greatly improved performance and reliability. The Rhodax was developed to replace secondary and tertiary crushing and the rod mill in conventional comminution circuits. The unit is therefore suitable for crushing, preliminary grinding and sometimes final grinding applications. Depending on the final product size distribution requirement, the Rhodax can be used in either open or closed circuit mode.

Description of the Rhodax

The Rhodax is an inertial cone grinder which means that the grinding parts are moved by rotating unbalanced masses, and not due to an eccentric mass as is the case for a conventional cone crusher. The mechanical layout of the machine is shown in the diagram below.

The ring describes a horizontal circular oscillation movement, caused by the rotation of two sets of unbalanced masses. These two sets of masses are synchronized with each other and subject the ring to a known and controlled mechanical force. This force creates a fragmentation force written as follows:

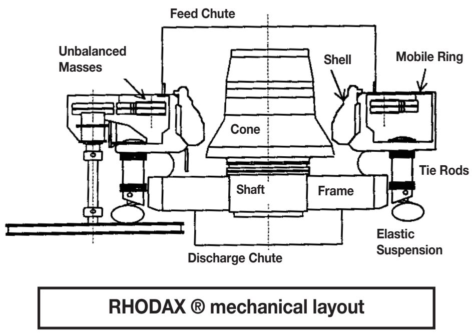

Figure 1—The Rhodax consists of a frame supporting a cone and a mobile ring. A series of tie rods form rigid links between the two parts and limit the vertical motion. The frame is mounted on an elastic suspension to isolate the foundations from the dynamic stresses generated during grinding. The frame contains a fixed central shaft onto which the grinding cone is mounted. The grinding cone is free to rotate. The vertical position of the cone, and hence the gap, is adjusted by means of a hydraulic sliding sleeve on the shaft. The required air gap can thus be obtained, and wear can be compensated for very easily. The air gap is equal to the average distance between the cone and the ring, and is therefore independent of the compression of the material bed.

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$$F = m \times e \times \omega^2$$

where F = fragmentation force
m = mass of unbalanced masses
e = eccentricity of unbalanced masses
ω = rotational speed of the unbalanced masses.

The fragmentation force for any given unit is known and can be changed by changing either

- the phase angle between the two sets of unbalanced masses, or
- the rotational speed of the unbalanced masses.

Operating principle

Compression grinding is based on a variation of the compactness of a material as a function of the mechanical stress applied to it, which is called the 'pressure-compactness' relationship. Compactness is defined as the quantity of solid material present in a given volume. It is therefore equal to the ratio between the apparent density and specific gravity. The conventional compactness for most bulk materials is in the order of 0.5 to 0.6.

During operation, the horizontal circular translation generates a cycle in which the two parts of the fragmentation chamber (cone and ring) move towards and away from each other. The material inside the fragmentation chamber undergoes a compression phenomen, followed by a forward on movement. During the separation phase, fragmented particles can move lower in the chamber until the next compression cycle. This process is illustrated in Figure 2.

The following three parameters can be changed on the Rhodax:

- the gap between the cone and the ring
- the total static moment of the unbalanced masses
- the rotational speed of these unbalanced masses.

The gap controls mainly the flow of material through the unit, and indirectly controls the power. The moment and speed of the unbalanced masses impose the fragmentation force, control the product size distribution and therefore the power absorbed by the machine.

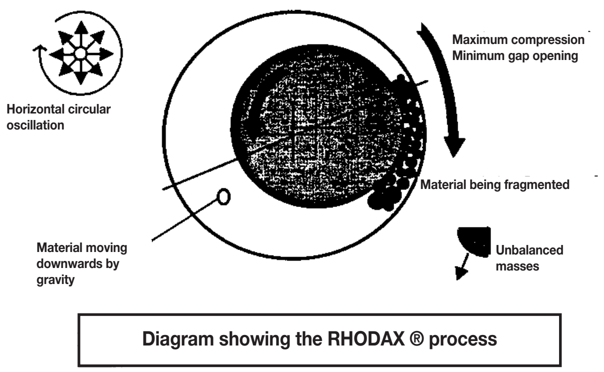

Figure 2—The number of compression - movement cycles which a particle will experience depends on the speed of rotation of the unbalanced masses and is typically in the order of 3 to 6. During these compressions, the cone rolls on a bed of material a few millimetres thick, at a speed of a few tens of a revolution per minute. The maximum pressure applied to the material bed is in the order of 10 to 50 MPa. The size grading of the material will be reduced in accordance with the pressure - compactness law characterizing the specific material. This increases the compactness by 5 to 20 per cent.

Current Rhodax range

FCB have developed a range of equipment ranging from a cone diameter of 80 mm to large industrial units with a cone diameter of 1200 mm. The various units are shown in Table I.

Rhodax at the AARL

The AARL have acquired a Rhodax 300 which was installed at the milling pilot plant in Centurion. Initially the unit was installed in open circuit mode and operated for a period of two years. During the initial two-year period the unit was operated in both wet and dry crushing mode. The Rhodax installation at the AARL pilot plant is the only one of its kind in Africa. A number of open circuit campaigns were performed as follows:

- Potgietersrus PGM ore
- Kimberlite
- SAG mill pebbles
- Waste rock

The unit has recently been commissioned in closed circuit to extend the capabilities of the Rhodax. The screen size can be varied between 1 and 10 mm to give a wide range of product size distributions.

Test procedure

The top size that the Rhodax 300 can accommodate is 40 mm. For this reason all samples to be tested in the AARL Rhodax have to be crushed to 100 per cent passing 40 mm. Any data produced from testwork using the Rhodax 300 can be scaled up to the larger units by FCB in France. An illustration of the scale up data is presented in Table II.

The important points to note from Table II are:

Table I

Series	80	150	200	300	450	600	800	1000	1200
Cone diam (mm)	80	150	200	300	450	600	800	1000	1200
Nominal gap (mm)	3	6	8	12	18	24	32	40	48
Capacity (t/h)	0.3	1.7	3.5	10	25	50	110	200	300

Table II

	Closed Circuit: 6 mm Screen			
Series	RX 300	RX 1000	RX 1200	RX 1400
Throughput (t/h)	3.3	65	100	150
Net Power Draw (kW)	1.8	360	540	810
Energy Consumption (kWh/t)	5.5	5.5	5.5	5.5
Circulating Load (%)	160	160	160	160
% passing 212 microns (%)	20	20	20	20
Max Feed Size	45	160	180	200

➤ the energy consumption is constant for the different sized units
➤ the product grading remains the same as the size of the unit increases
➤ the circulating load remains the same as the size of the unit increases
➤ the reduction ratio increases as the size of the unit increases.

Depending on the complexity of the test programme, between 5 and 50 tons of material are required.

Open circuit test results

The open circuit test programme was initiated to gain an understanding of the range of operation of the Rhodax on Witwatersrand-type ores. All the tests were performed in open circuit mode. The results from the open circuit test programme have been condensed into the following four graphs which highlight specific operational characteristics of the Rhodax.

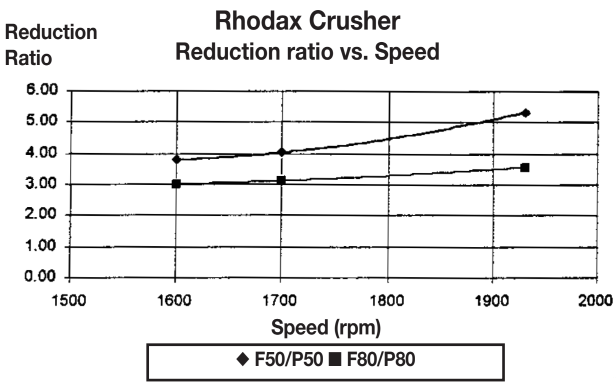

Figure 3—Shows the reduction ratio as a function of the rotational speed of the unbalanced masses. The gap was set at 10 mm. The reduction ratio is expressed as the ratio of both the d50 and d80 of the feed and product size distributions. As expected the reduction ratio increases as the speed of the masses increases. What is important to notice is the divergence of the two curves at the higher speeds. This is indicative of the operation of the Rhodax and is caused by the relative increase in the amount of fines produced at the higher operational speeds. This means that the shape of the size distribution of the product material can to a certain extent be controlled by the rotational speed of the masses. The speed of the masses has little effect on the throughput, as will be shown in the next Figure.

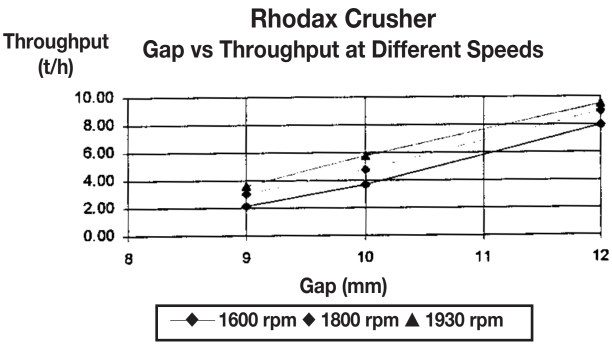

Figure 4—Shows the effect of the gap setting on the throughput. The throughput increases as the gap setting increases. The graphs also show the relative insensitivity of the throughput on the rotational speed on the masses.

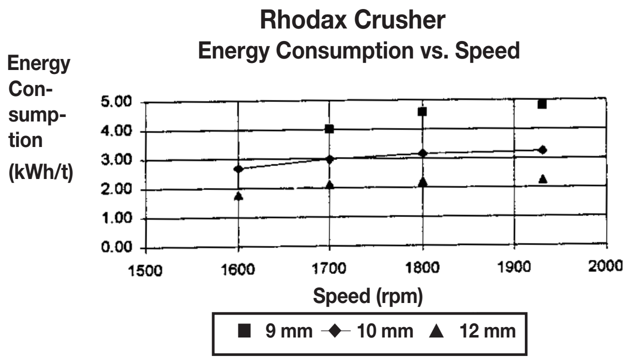

Figure 5—Shows the energy consumption as a function of the rotational speed of the masses. The energy consumption is essentially constant over the operational range of rotational speeds. The energy consumption, however, increases as the gap setting is decreased. This is due to the reduced throughput at the lower gap settings.

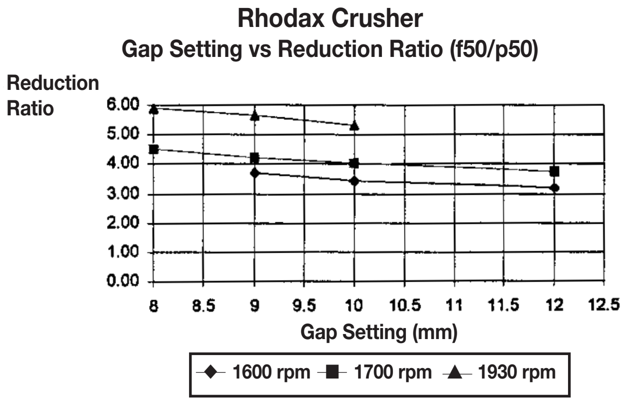

Figure 6— Shows the effect of the gap setting on the reduction ratio at different speeds. The curves show that the reduction ratio is essentially independent of the gap setting and is a strong function of the rotational speed of the unbalanced masses. The reason for the independence of the reduction ratio on the gap setting is because breakage is taking place by inter-particle crushing in the compressed bed and hence is only a function of the pressure exerted on the bed.

The effect of the operating parameters of gap setting and rotational speed of the unbalanced masses can be summarized as follows:

Gap setting : controls throughput
Rotational speed : determines shape of product particle size distribution.

By manipulation of the above parameters, the Rhodax can produce a product size distribution specific to the client's needs.

Closed circuit test results

The preliminary closed circuit test results are summarized on the next page. Further work is being performed to optimize the closed circuit configuration in terms of optimum product size and energy consumption.

The Rhodax crusher was operated in closed circuit with a 3 mm screen. The feed to the Rhodax was crushed to 100 per cent passing 45 mm and the 3 mm material removed. The results of the three closed circuit tests are presented in Table III.

Table III

Test No	Feedrate (t/h)	CLR (%)	Reduction Ratio (F50/P50)	Energy (kWh/t)
1	3.41	205	18.22	5.68
2	2.86	202	12.52	6.78
3	3.14	183	11.97	7.70

Test 1 was performed without removing the –3 mm material while the remainder of the tests were performed on the –45 +3 mm material. In Test 1 the –3 mm material accounted for approximately 21 per cent of the feed. This accounts for the high feedrate and reduction ratio and the low energy consumption.

Tests 1 and 2 were performed at a speed of 1700 rpm while the speed was increased to 1750 rpm in Test 3. This increase in speed accounts for the increase in energy consumption. Associated with the increase in speed is an increase in the feedrate and a decrease in the circulating load.

The circulating loads are generally lower than anticipated and indicate that the Rhodax is fully capable of producing a fine product with high reduction ratios. The low circulating load is beneficial in terms of the screening and material transport systems.

The size distributions for the three tests are presented in Figures 7 to 10. The effect of increasing the speed is shown in the Rhodax discharge size distribution—the increase in speed results in a finer size distribution from an identical feed.

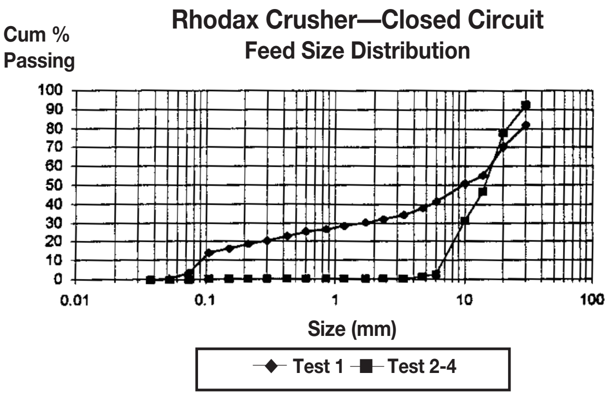

Figure 7

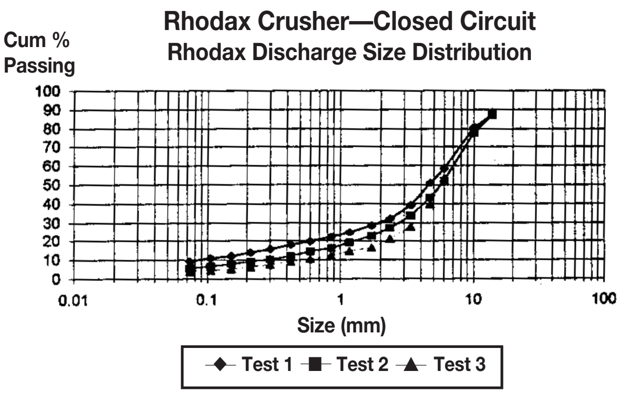

Figure 8

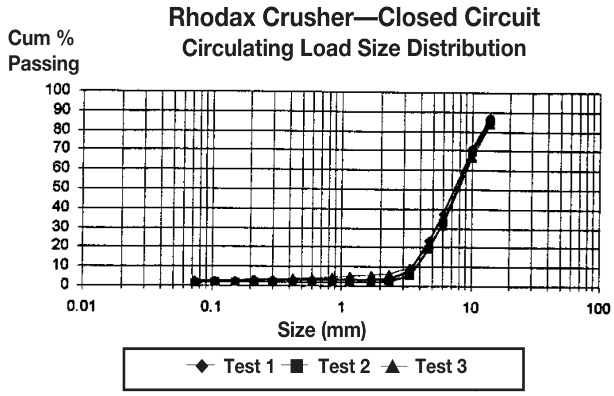

Figure 9

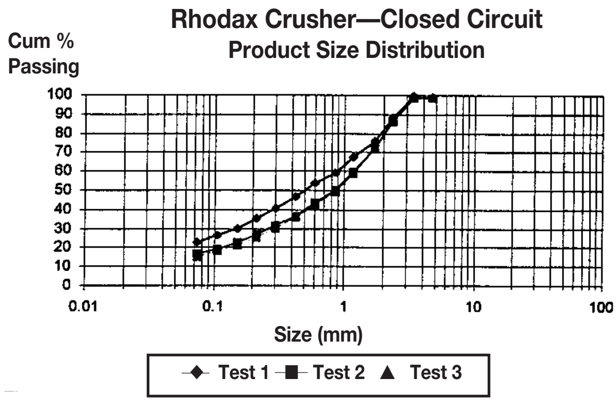

Figure 10

Applications of the Rhodax in the metallurgical industry

The Rhodax crusher has many advantages over conventional crushing circuits. These advantages are discussed below.

- No extensive foundations are required due to the fact that the unit is mounted on elastic suspension which prevent the dynamic stresses from being transmitted to the foundations. The Rhodax can be skid mounted to allow the unit to be moved from site to site.
- The footprint of the unit is small compared to other conventional crushing circuits.

At present specific applications are being investigated for the Rhodax as follows:

- Rhodax/Ball mill circuits are being looked at as a replacement for the conventional ROM milling circuits. It is expected that the Rhodax/Ball mill circuit will be able to produce a produce size distribution which is better suited to the down stream processes
- The Rhodax is ideally suited to ROM mill pebble crushing applications due to the small footprint and high reduction ratio
- A single closed-circuit Rhodax can replace both the secondary and tertiary crushers in a conventional circuit.