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The influence of mill speed and pulp density on the grinding efficiency for secondary stage grinding

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Magotteaux, with the co-operation of Anglo Platinum, has erected a fully instrumented pilot plant at Frank concentrator, which is being used to study the influence of a variety of grinding parameters. This paper will discuss only the influence of mill speed and pulp density on secondary stage grinding. A ∅ 0.82 x 1 m open circuit mill was used with reclaimed Merensky tailings as feed.

The conclusions apply to this pilot plant but further investigation needs to be done to verify whether the same trends will be applicable to a large industrial-scale mill.

Pilot plant description

The milling pilot plant consists of two containers mounted on top of each other (see Figures 1 and 2).

The bottom container holds the mill, the drive train, rollers and the high-tension cabinet.

The feed boxes (fine and coarse feed) are built into the top container.

The sizes of the available mills are:

- ∅0.82 x 1.0 m (used for the testwork described below)
- ∅1.3 x 2.2 m.

The following parameters are measured online:

- Mill inlet water (*l*/h)
- Mill outlet water (*l*/min)
- Speed (rpm)
- Mill torque on the driving shaft (Nm)
- Electric power (kW)
- Mill weight (kg)
- Throughput (kg/h).

The absorbed power is calculated by multiplying the torque on the driving shaft with the shaft speed (rad/sec) and hence excludes any losses associated with the gearbox and motor.

The pulp weight in the mill is obtained by subtracting the mill weight during the test from the empty mill weight, including the ball charge, at the start of the test. The pulp volume of the pulp in the mill is then calculated using the mill discharge density (before dilution) obtained during the sampling.

The ball charge, and hence the volume of the voids between the balls in the mill, is known and we are then able to calculate the factor 'volume pulp/volume voids between the balls'.

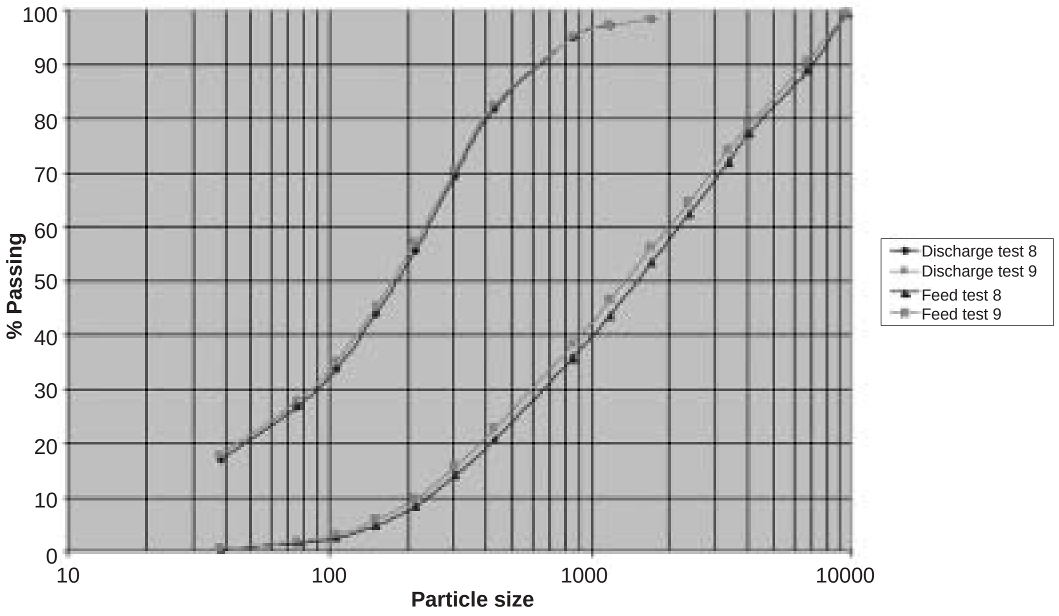
Repeatability

The repeatability of the pilot plant was investigated in the past with 2 repeat test runs with the ∅0.82 x 1 m grate discharge mill in open circuit with a charge in equilibrium with a ∅60 mm ball top-up and a 32.4% ball filling degree. The data (see Table I) and particle sizes (see Graph 1) are mentioned.

Overall, the repeatability is good as the variations between tests 8 and 9 are small. There is only a 10 μm difference in the P_{80}, and a 1% difference in the %<75μm, and the particle size tendencies are correct (the finest feed gives the finest discharge).

Figure 1. Pilot plant showing the mill

Figure 2. Pilot plant feed conveyor



Graph 1. Repeatability tests particle size distributions

Table I
Repeatability testing data

	Test 8	Test 9
% solids mill discharge	80.3	80.0
Speed (%V_{crit})	73.70	73.7
Throughput (kg/h)	800	801
Absorbed power (kW)	5.25	5.24
Wi (kWh/T)	6.56	6.54
KWh/t–75 µm	26.0	25.23
% < 75 µm	27.0	28.0
F_{80} (µm)	4405	4157
P_{80} (µm)	400	390
W_{io} (kWh/T)	18.8	18.6
V_{pulp}/V_{voids} (%)	120	112

In addition, the W_i and W_{io} are almost identical.

It was felt that two repeats were adequate to illustrate the repeatability, as the changes described further in this paper are so large that the variation of the investigated parameters would be substantially greater than the repeatability error.

Mill speed

These tests were done with the ∅0.82 x 1 m overflow mill with a 30 mm graded ball charge and a 30% filling degree.

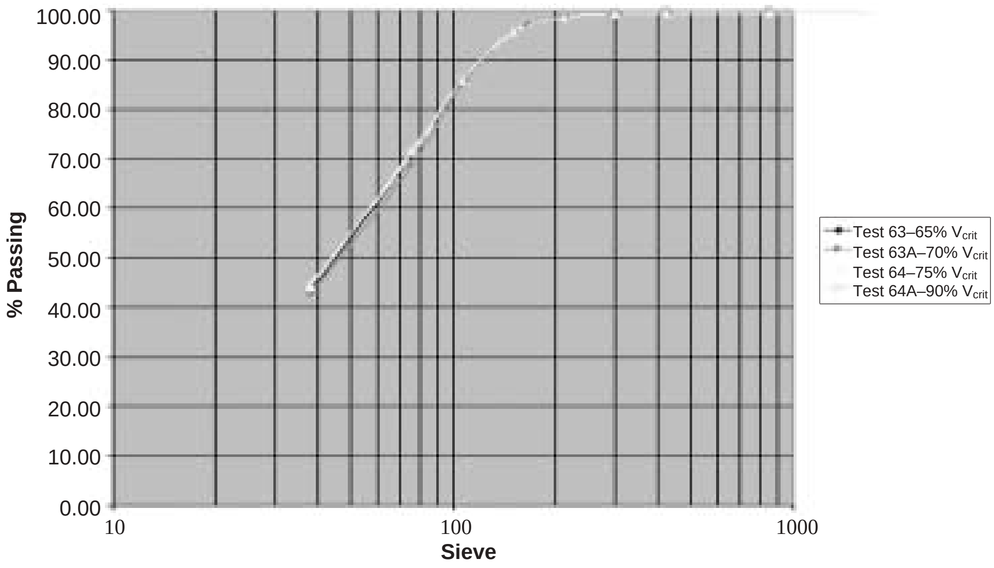
The speed was increased from 65% to 90% V_{crit}.

The data is summarized below (see Table II).

Contrary to common belief, it can be seen that the extra power input obtained by increasing the speed from 65% V_{crit} to 90% V_{crit} does not result in a finer grind in this case. The best grinding efficiency measured in terms of

Table II
Pilot plant data for different speeds

	65% V_{crit}	70% V_{crit}	75% V_{crit}	90% V_{crit}
Dry Feed rate (kg/h)	288	288	288	288
Speed (rpm)	30.40	32.90	35.16	41.99
% V_{crit}	65.08	70.43	75.27	89.89
Absorbed power (kW)	3.616	4.077	4.637	5.658
W_i (Kwh/T)	12.575	14.136	16.100	19.659
% solids	73.7	73.5	73.4	73.4
Mill discharge density	1.998	1.993	1.988	1.988
F_{80} (micron)	203	203	207	207
P_{80} (micron)	91.7	93.9	90.7	91.3
W_{oi} (Kwh/T)	36.8	42.9	45.4	55.9
Kwh/T -75 micron	30.9	36.6	36.9	45.8
Kwh/T -150 micron	40.0	45.4	48.7	59.9
Kwh/T -212 micron	73.8	82.6	91.2	110.1
Ratio V_{pulp}/V_{voids}	321	315	319	318
Weight of solids in mill (kg)	292	285	287	286
Retention time (min)	61	59	60	60
% < 75 micron	70.7	68.6	71.6	70.9



Graph 2. Particle size distribution for different mill speeds

Table III
Pilot plant data for different pulp densities

	68.8 % solids	73.4% solids	75.9% solids
Ore solids density	3.1	3.1	3.1
Dry feed rate (kg/h)	289	288	287
Speed (rpm)	35.31	35.11	35.00
% V_{crit}	75.59	75.17	74.92
Absorbed power (kW)	5.335	5.628	5.338
Wi (Kwh/T)	18.446	19.547	18.584
% solids	68.8	73.4	75.9
Mill discharge density	1.872	1.989	2.058
F_{80} (micron)	217	203	203
P_{80} (micron)	83.3	77.3	81.4
W_{oi} (Kwh/T)	44.2	44.8	45.6
Kwh/T -75 micron	40.2	38.9	38.6
Kwh/T -150 micron	50.9	56.9	54.9
Kwh/T -212 micron	89.9	110.7	105.2
Ratio V_{pulp}/V_{voids}	145	162	199
Weight of solids in mill (kg)	115	146	192
Retention time (min)	24	30	40
% < 75 micron	75.2	78.7	76.6

Operating Work Index (W_{io}) or 'Kwh/T passing a certain screen' is obtained with the lowest speed. The extra power input achieved by increasing the speed does not seem to have any effect and does not result in a finer grind.

The particles size distribution slope is not affected by the mill speed (see Graph 2) as the curves are mostly overlapping.

Density

These tests were done with a ∅0.82 x 1 m grate discharge mill with a 30 mm graded ball charge and a 30% filling degree.

The mill discharge pulp density was increased from 68.8% to 75.9% solids.

The data is summarized in Table III.

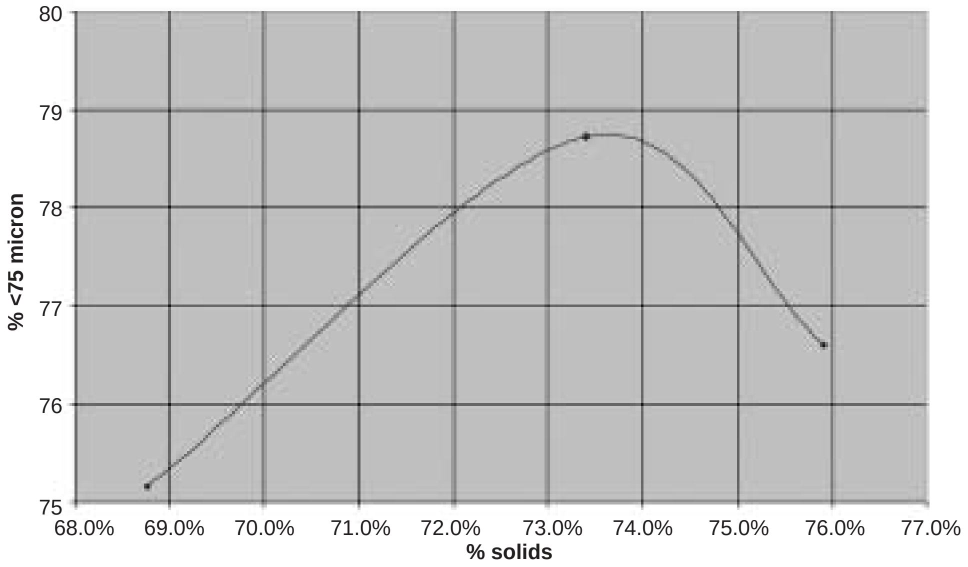
The example in Table III illustrates that the density has a large influence on the grinding efficiency. In this case, the optimum %<75 μ is in the region of 73.4% or 1.989 kg/*l* (see Graph 3).

If one goes below that, the higher dilution will 'flush' the fines out of the mill and reduce the overall residence time in the mill. This will result in a coarser grind with a slightly steeper particle size distribution curve (see Graph 4).

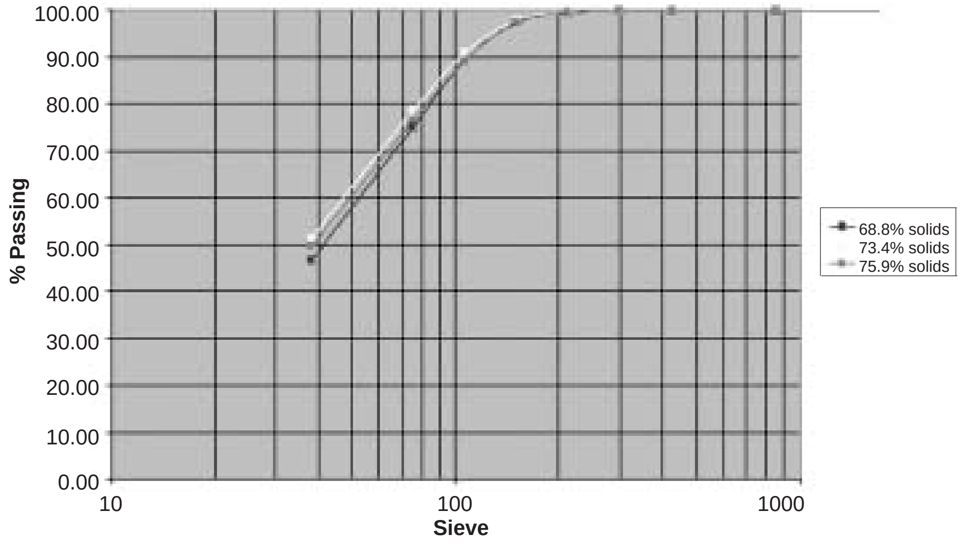
If one increases the density, the pulp will become too sticky and the ball charge expands. The balls become coated and the grinding efficiency decreases.

The pilot mill is also equipped with a sensor measuring the 'ball and pulp toe and shoulder angles' (see Figure 3). These data are then used to calculate the total pulp and ball charge angle (see Graph 5).

Graph 5 clearly illustrates how the ball charge stays quite compact till about 73% solids as the total media angle does not change. However, once one goes above this, the media charge starts expanding due to the high pulp viscosity and ball coating.



Graph 3. %<75 µ in function of the mill discharge % solids



Graph 4. Particle size distribution for different densities

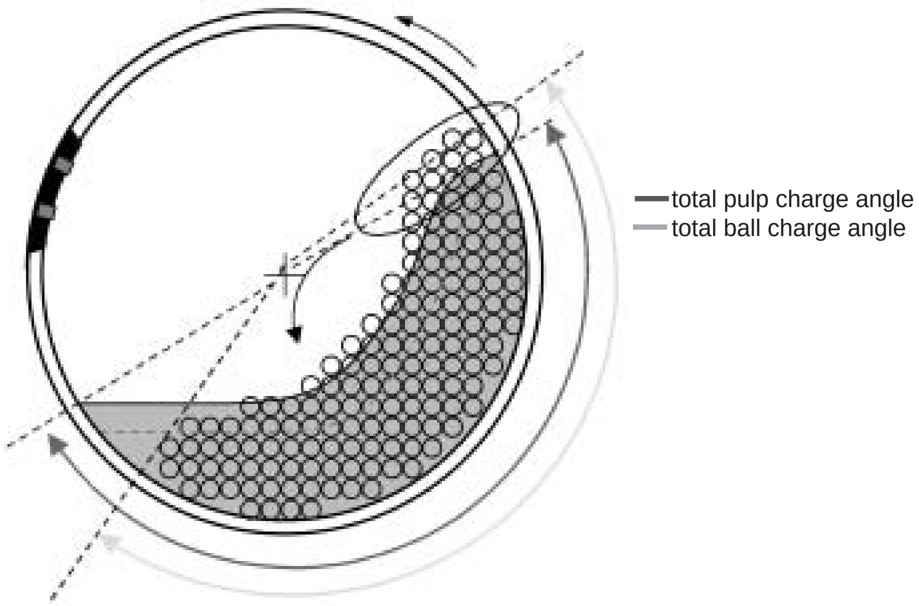
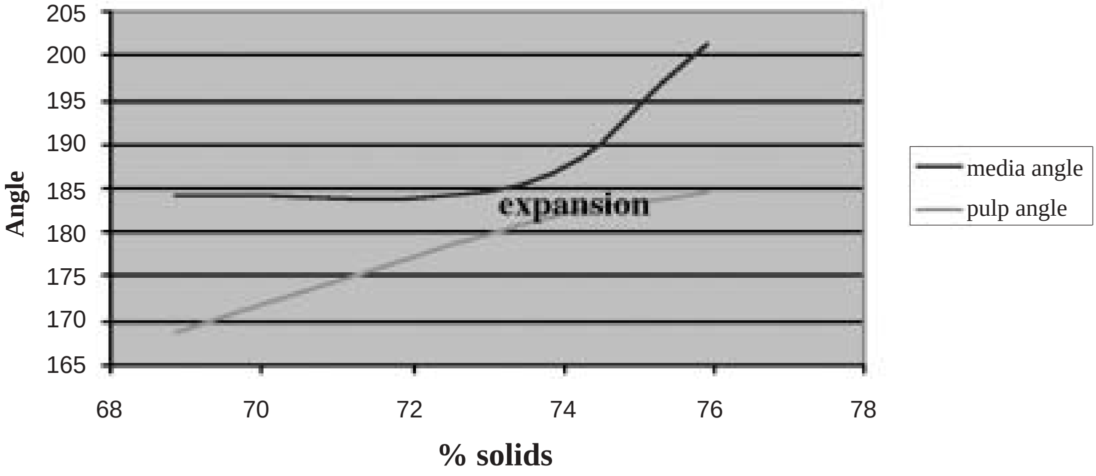


Figure 3. Pulp and ball charge angles



Graph 5. Pulp charge and ball charge angles

The pulp volume, on the other hand, increases linearly with the pulp % solids.

Conclusions

The influence of mill speed

Increasing the speed from 65% V_{crit} to 90% V_{crit} does not result in a finer grind in this case.

The best grinding efficiency measured in terms of Operating Work Index (W_{io}) or 'Kwh/T passing a certain screen' is obtained with the lowest speed.

The extra power input obtained by increasing the speed does not have any effect and does not result in a finer grind.

However, one should bear in mind that this testwork was done on a small pilot plant mill. The tendencies on a large mill might not be the same. It would be advisable to conduct plant surveys on a large scale mill equipped with a variable speed drive to validate this work.

The influence of pulp density

Pulp density has a large influence on the grinding efficiency. In this case, the optimum is in the region of 73.4% or 1.989 kg/*l*.

If one goes below that, the higher dilution will 'flush' the fines out of the mill and reduce the overall residence time in the mill. This will result in a coarser grind with a slightly steeper particle size distribution curve.

Increasing the density will make the pulp more sticky and the ball charge expands. The balls are being coated and the grinding efficiency decreases.

Acknowledgements

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