A quick test procedure for the determination of milling parameters

by D. MENNE*, B.Sc. (Ing. Chem.)

SYNOPSIS

A comminution model and a quick laboratory milling test procedure are presented. These allow the determination of milling parameters for the

— optimization of ball size and pulp density in operating mills
— estimation of the performance of new feedstocks in an existing mill
— estimation of the expected milling performance for a new project.

Information on the estimation of the size of mills to deliver specified amounts of comminution energy, and of the amount of expected ball, rod, and liner wear to allow cost estimates for new projects, is also included.

SAMEVATTING

'n Model van die maal-proses en 'n vinnige laboratorium toetsprosedure word voorgelê. Dié laat die bepaling van maal-parameters toe wat gebruik kan word om:

— die bal-grootte en vlodder-digtheid in bestaande meule te optimiseer
— die deurset van nuwe toevoermateriaal in bestaande meule te raam
— die vermoëns van 'n nuwe maal-aanleg te raam.

Inligting word ook verskaf om ramings te maak van meulgroottes benodig om vasgestelde maal-energie oor te dra asook die verwagte slytasie van balle, stawe en voerings sodat kosteberamings vir nuwe projekte uitgevoer kan word.

Introduction

The widely accepted test for Bond Work Index requires feedstock that can be prepared as a minus 3,26 mm product, and becomes very onerous when products much finer than 0,2 mm are examined. Testwork based on more modern theories of selection and breakage functions is onerous, and the scale up has not yet been proved. This is a significant problem in the development of flowsheets for some carbon-in-pulp projects, where effective re-treatment of sand tailings dumps requires some milling to polish off old coatings of oxide or to provide additional liberation of the gold.

Some years ago the author developed a grinding equation and a milling test procedure that are applicable to a wide range of particle sizes, and that allowed easy and rapid scale up. The procedure provided good predictions for some half a dozen different materials used in the iron and steel industry. Furthermore, the grinding equation provided a means of monitoring the performance of operating mills, and of obtaining quantitative data for the optimization of the size and mass of grinding charges.

This note is intended to record the procedure and scaling methods used since it is felt that they could be of use to other extractive metallurgists.

Grinding Equation

When grinding media are of a size that is adequate for breaking the largest particles, the size distribution of the product can often be related to the size distribution of the feed by

$$Y = Y_0 \exp(-KEx^a), \qquad (1)$$

where

Y = cumulative mass percentage larger than size x after milling
Y_0 = cumulative mass percentage larger than size x in feed
K = a constant for the mill and ore
E = unit milling energy
= kilowatts drawn by the mill per ton of solids per hour flowing through the mill for continuous milling
= kilowatt-hours used by the mill per ton of solids charged in a batch mill
x = particle size
a = a constant for the mill and ore.

In rod mills, the larger particles bear the brunt of the impacts, so protecting the smaller particles. Thus, K for the larger particles is larger (typically 1,5 times) than K for the smaller particles.

Application to an Operating Mill

A plot of $\ln(Y_0/Y)$ versus x on three-cycle log–log graph paper is shown in Fig. 1. In the fines region, the plot should always be linear. The slope of the plot gives the exponent a; KE is the intercept at $x = 1$. Any drooping in the upper region indicates that the balls are too small; in theory, the diameter of the maximum ball size should be increased by at least

$$(d_m/d_d)^{0,5},$$

where

d_m = maximum particle size showing excessive build-up (being rounded to the shape of river pebbles in the circuit)
d_d = particle size at which drooping starts to occur (smallest particle size being rounded to the shape of river pebbles rather than being cracked).

In practice, the reduction in liner life and the loosening of bolts may prescribe a compromise such as the insertion of only a few large balls, or the investigation of other alternatives such as finer crushing of feedstock.

Since the comminution energy is used very inefficiently when particles are abraded and rounded rather than

* Edward L. Bateman Limited, P.O. Box 565, Boksburg 1460, Transvaal.

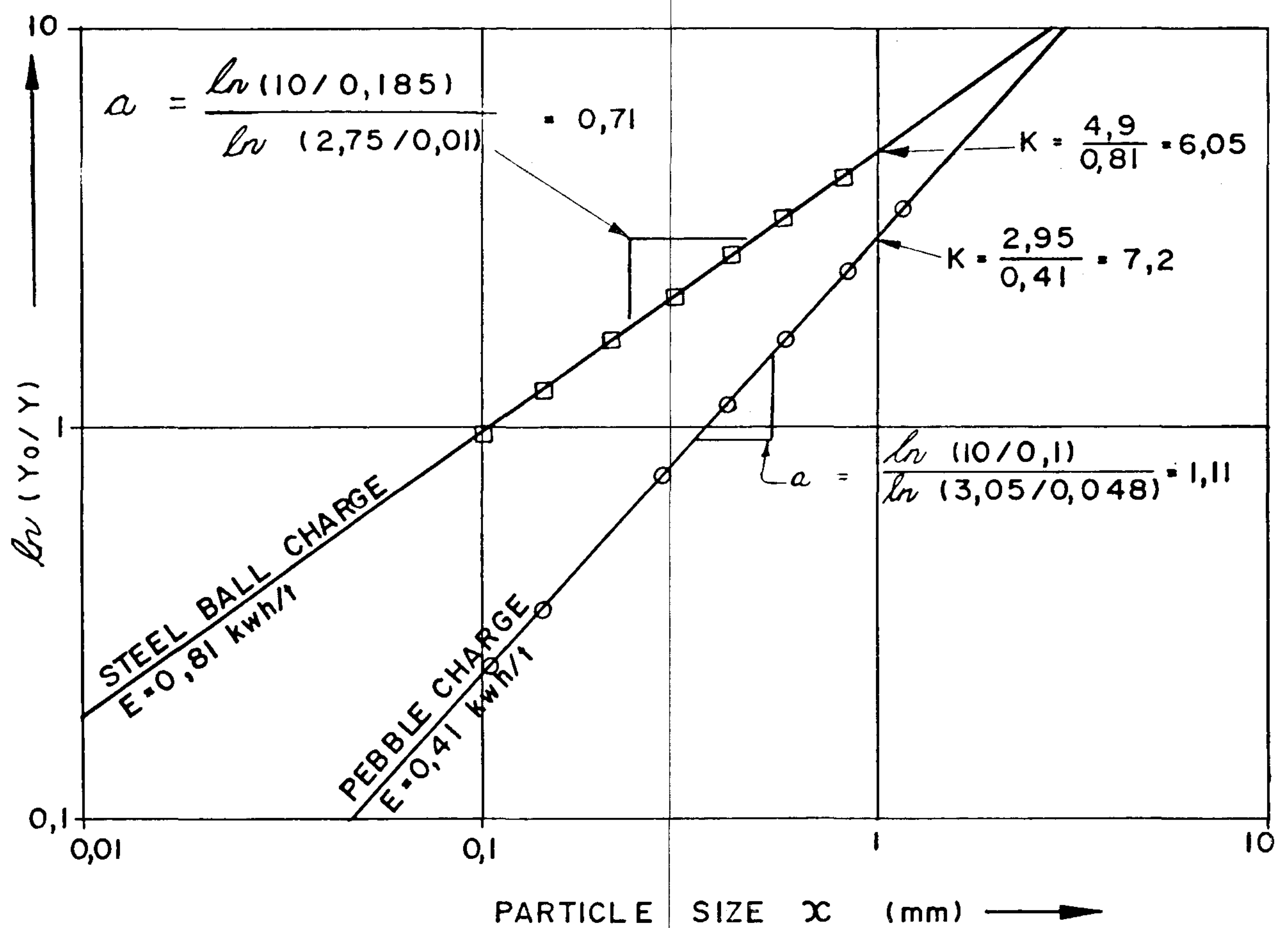

Fig. 1—Graph showing milling parameters

cracked, one's immediate reward on inserting balls of adequate size will be a modest (5 to 10 per cent) increase in throughput. The elimination or reduction of the abrading mechanism will generally also reduce sliming of the ore, which is advantageous for flotation, thickening, filtration, and reduction of water in fine tailings. Improvements in the operation of any classifying or recovery equipment taking the coarse mill product can also be expected.

Predictions

Once K and exponent a have been determined for a given mill and pulp, many variables can be examined on paper before costly changes are executed on a plant. Prediction should generally be attempted only within the particle-size range where the correlation in equation (1) is valid, i.e. where the relationships for the graphical plot are linear.

Changes in Production Rates or Fineness

Any changes in feed rate or ball charge affect E, and the new Y's can be calculated directly by substitution of the new E into equation (1).

Optimization of Operating Variables

Different ball sizes and pulp densitites can be tried in a laboratory mill until the maximum value of K is obtained. The same pulp density and a ball size $(D_o/D_t)^{0,3}$ smaller than that used in the test mill can be used on the operating mill to improve its performance, where

D_o = diameter of operating mill, m
D_t = diameter of test mill, m.

Unfortunately, the maximum ball diameter that can be effectively used in a test mill is limited to about $D_t/10$.

New Feedstock in an Existing Mill

K and the exponent a are determined for the existing feedstock in the operating and the test mills, and for the new feedstock in the test mill. K and the exponent a are then estimated for the new feedstock in the operating mill by multiplication of the test-mill values by K_o/K_t and a_o/a_t respectively, where the subscripts o and t denote the values obtained on the existing feedstock in the operating and test mills respectively.

Milling Performance for a New Project

Where such testwork cannot be conducted, it can be presumed as a first approximation that K and the exponent a will not change on scale-up.

K is determined for the ore in a mill that has a known or calibrated power draw, e.g. the ball mill of the Standard Bond Work Index, which draws about 60 J per revolution.

The E required for the requisite fineness can then be easily determined by re-arrangement of equation (1) and substitution of the values Y, Y_o, x, and K and the exponent a therein.

A mill having the necessary power draw to give the required E at the rate at which the feedstock must be milled can then be readily chosen. This choice will be conservative, since the efficiency of utilization of the power drawn increases by a factor $(D_o/D_t)^{0,2}$ owing to better cascading of balls as the mill diameter increases. After installation, the fineness of the product can be adjusted by reductions in the ball charge.

Conclusion

It should be remembered that a charge volume equal to the interstitial ball space should always be used for batch tests.

It is useful to be able to have a rough estimate of the maximum power than can be drawn by a mill. In general,

$P = AL\,D_o^{2,4}$,

where

P = power drawn, kW·h

A = 11,2 for steel balls or rods (at 75 per cent critical speed)

= 5,9 for siliceous pebbles (at 85 per cent critical speed)

L = mill length, m.

TABLE I

CONSUMPTION OF MILL CHARGE AND LINERS

Feed	Mill	Charge	Liner
Wet	Ball	$0{,}16(Ai-0{,}015)^{0{,}33}$	$0{,}012(Ai-0{,}015)^{0{,}30}$
Wet	Rod	$0{,}16(Ai-0{,}020)^{0{,}20}$	$0{,}016(Ai-0{,}015)^{0{,}30}$
Dry	Ball*	$0{,}023\,Ai^{0{,}5}$	$0{,}0023\,Ai^{0{,}5}$
Dry	Rod	$0{,}018(Ai-0{,}020)^{0{,}20}$	$0{,}0018(Ai-0{,}015)^{0{,}30}$

* Only for values of Ai up to 0,22.

TABLE II

TYPICAL VALUES OF Ai

Material	Ai
Dolomite	0,016
Shale	0,021
Limestone	0,024
Cement clinker	0,071
Magnesite	0,078
Heavy sulphides	0,13
Copper ore	0,15
Hematite	0,16
Magnetite	0,22
Gravel	0,29
Trap rock	0,36
Granite	0,39
Taconite	0,62
Quartzite	0,78
Alumina	0,89

Estimates of charge and liner consumption are generally needed when flowsheets developed from this sort of testwork are costed. These estimates can be made, in terms of kilograms of metal per kilowatt-hour of mill energy consumed, from the equations and constants listed in Tables I and II.

Bibliography

1. Bond, F. C. Crushing and grinding calculations. *Brit. Chem. Engng*, vol. 6, no. 6. Jun. 1961. pp. 378 – 384, and vol. 6, no. 8. Aug. 1961. pp. 543 – 548.
2. Lowrison, G. C. Crushing and grinding. London, Butterworths, 1974.
3. Lynch, A. J. Mineral crushing and grinding circuits. Oxford, Elsevier, 1977.
4. Mular, A. L., and Bhappu, R. B. Mineral processing plant design. SME/AIME, 1978.

CMMI Congress

The Australasian Institute of Mining and Metallurgy is to host the 13th Congress of the Council of Mining and Metallurgical Institutions in Canberra from 11th to 16th May, 1986.

Business and technical sessions will be held in Canberra from 11th to 16th May, and pre- and post-Congress tours will be arranged to mining and metallurgical centres in Australia and New Zealand.

Further details will be announced later.