Breakage rates of mixed skarn tungsten in a laboratory mill

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ABSTRACT: The effect of grinding in different pure mineral has been generally studied. However, very little work has been done in mixed skarn tungsten. This paper describes the breakage rates of the mixed skarn tungsten from milling kinetics at a laboratory ball mill. Firstly, the breakage rates of different particle sizes in constant operating conditions have been done in a ball mill having 13.5 cm diameter and 14.6 cm length, such as mill speed, slurry density and media size. Secondly, tests were conducted in the best suitable grinding condition to studied the grinding performance in the mixed skarn tungsten. Test results indicates that the specific rates of breakage (k_i) value increasing as feed size fraction increased excluded -2+1mm fraction because the ball size is too small to break the coarser particles. The bigger ball loads (30, 40 mm size) was significant for breaking the particles larger than 0.3 mm, smaller ball loads (20 mm size) was at work on the particles smaller than 0.3 mm. It should be noted that the above operation condition have verified with further industrial.

Introduction

Grinding is widely used in the preparation of raw materials on mining industry and cement industry. Grinding is an energy-consumption operation since some of the energy during grinding is converted to heat and voice that is not utilized fully in grinding process[1]. Thus, grinding is not very efficient operation and it needs to be worried about carefully.

Tungsten ore, of which Hunan and Jiangxi province have larger reserves in China with over 50% share, are very commonly applied in some branches of industry in different ways. Most of the China's commercially ecoverable tungsten reserves are mixed skarn type tungsten ore, quartz vein type tungsten, porphyry type tungsten and so on. Mixed skarn type tungsten ore mostly contained scheelite(CaWO4) and wolframite[(Fe, Mn)WO4]. It has many important uses such as in the production of tungsten steel, tungsten alloy, military, aviation, petroleum chemical, textile and plastic, etc. [2]

In grinding circuit, ball mill and hydraulic cyclone were used widely in mineral processing. However, grinding is a complex and energy-consumption operation that it’s fundamental is not cleared completely, so in order to make the grinding more efficient, kinetics of grinding in the mills has been developed as applicable models [3]. Kinetics of grinding contained linear grinding kinetics and nonlinear kinetics, Linear kinetics can be expressed either on the basis of grinding time or energy consumption. Nonlinear kinetics are caused by energy transfer mechanisms in the comminution machine whereby coarser particles might be ground preferentially or are protected by fines, by energy dissipation through interparticle friction in compressed bed comminution, and sometimes from heterogeneities produced in the feed particles[4].

This paper aimed to analyze grinding rates and grinding condition of mixed skarn tungsten ore in Chenzhou city, Hunan province in terms of breakage rates using a batch-mill in lab.

Experimental studies

Materials

Mixed skarn tungsten sample was obtained from Hunan shizhuyuan nonferrous metals co.,ltd, China. The sample of mixed skarn tungsten was prepared and used throughout the grinding tests. The density of mixed skarn tungsten was 2.78 g/cm^3, the compressive strength was 1149.44 kg/cm^2.

Grinding tests

Grinding tests were carried out in a 13.5×14.6 cm steel ball laboratory mill at constant operating condition of mill such as media mass, mill speed and media size. The characteristics of the mill used in grinding tests and the grinding conditions are listed in Table 2.

Table 1 Mill characteristic and grinding conditions

Mill	Diameter, D, cm	13.5
	Length, L, cm	14.6
	Volume, V, cm3	2088.8
	Speed, rpm	85
	Critical speed, Nc	115.4
Mill charge	Diameter, d, mm	30 23 18
	Number	8 47 40
	Total mass, g	4078.8
	Specific gravity, g/cm3	4.8
	Charge rate	40.68
Material	Total powder weight, g	200
	Mixed skarn tungsten specific gravity, g/cm3	2.78

Each fraction samples were ground individually as batch-wise for 2, 3, 4, 5, 6 and 7 min to obtain both the breakage parameters and particle size distributions. Each samples were ground individually as batch-wise with difference ball diameter in 4 min to obtain both the breakage parameters and particle size distributions. Each samples were ground individually as batch-wise with difference grinding density in 4 min to obtain both the breakage parameters and particle size distributions. Sample was sieved by wet and dry screening to determine size distributions.

Result and discussion

Fig. 1 shows the first-order disappearance plot for the wet grinding of -2+1, -1+0.5, -0.5+0.3, -0.3+0.15, -0.15+0.1, -0.1+0.074 mm mixed skarn tungsten using a dispersing agent.

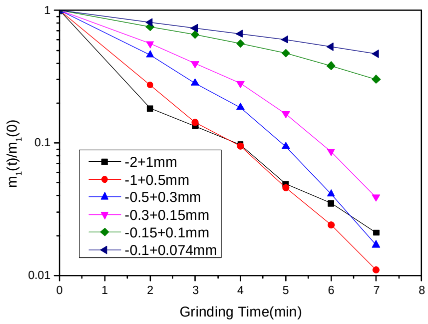

Fig. 1 First-order plot for wet grinding of mixed skarn tungsten

The ki values are estimated from the average slopes of the plots (Fig. 1) represented mathematically as Eqs. (2) and (3).

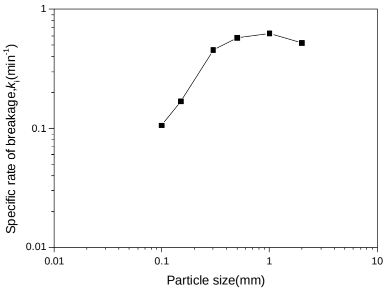

Fig. 2 Variation of the specific rate of breakage with size

Fig. 2 shows the variation of ki values against particle feed sizes. The values increase sharply until 1mm. This means that there is an optimal feed size (in this condition, approximately -1+0.5mm size fraction) where the greatest breakage occurs. The specific rate of breakage increases up to -1+0.5 mm feed size, but above this size fraction breakage rates decrease sharply for both grinding charges, since the particles are too large and strong to be properly nipped and fractured, and have a slow specific rate of breakage.

For same feed size, the size distributions of products after grinding for various determined grinding time under the same ball media are given in Fig. 3.

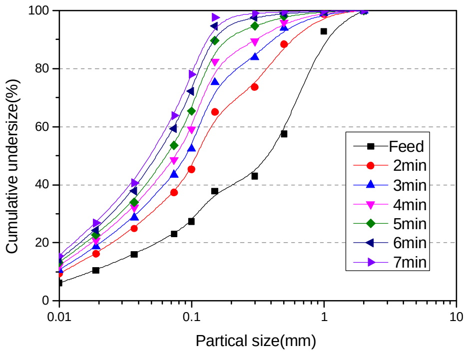

Fig. 3 Particle size distribution of product with time in which mixed ball size

Size distributions in each test became finer regularly according to grinding time.

The size distributions for 4 min grinding time are plotted in Fig. 4 in order to compare the effect of different ball media in same graph.

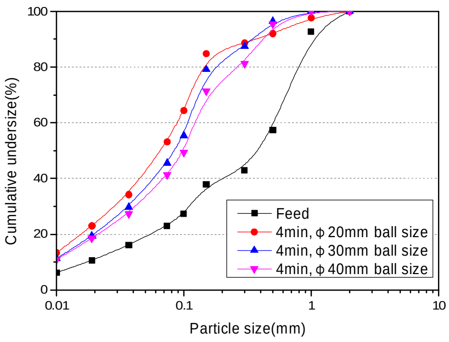

Fig. 4 Particle size distribution of product with different ball size after 4 minute grinding time

It can be seen that coarser ball media in which 40 mm, 30 mm top size ball diameter would lead to rapid disappearance of coarser particles than finer ball media in which 20 mm top size ball diameter. As seen in Fig. 4, the difference in size distributions of obtained by finer and coarser ball loads was significant for the particles larger than 0.3 mm. Coarser ball loads were found to be efficient for coarser particles having larger energy for breakage. However, finer ball loads having larger surface area were efficient for particles smaller than 0.3 mm.

The size distributions for 4 min grinding time are plotted in Fig. 5 in order to compare the effect of different grinding density in same graph.

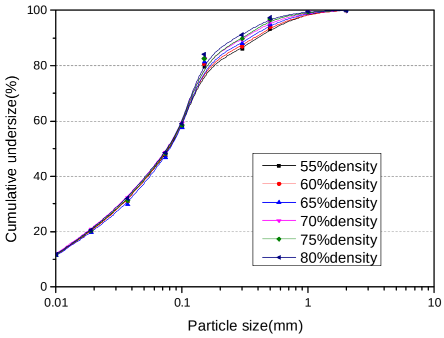

Fig.5 Particle size distribution of product in different grinding density after 4 min grinding time

As seen in Fig. 5, the difference in size distributions of obtained by 65% grinding density was decreased for the particles smaller than 0.1 mm. Higher grinding density were found to be efficient for coarser particles having larger collision probability.

The size distributions for 4 min grinding time are plotted in Fig. 6 in order to compare the effect of different mill speed in same graph.

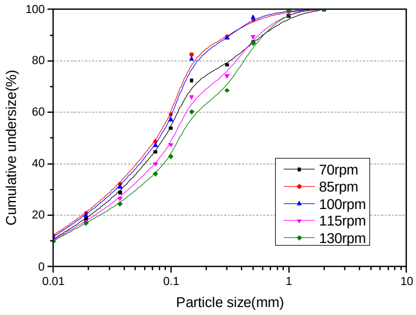

Fig.6 Particle size distribution of product in different mill speed after 4 minute grinding time

As seen in Fig. 6, the difference in size distributions of obtained by 85 rpm and 100 rpm was significant for the particles larger than 0.15 mm. Lower mill speed was found to be inefficient for particles having smaller collision probability. Meanwhile, Higher mill speed was exceeded critical speed that having less grinding ability.

Conclusions

(1) The ki values of -2 + 1, -1 + 0.5, -0.5 + 0.3, -0.3 + 0.15, -0.15 +0.1, -0.1+0.074 mm feed fractions of mixed skarn tungstne ground with mixed ball were obtained to be 0.52, 0.62, 0.58, 0.45, 0.17 and 0.11 min-1, respectively. This indicates that the specific rates of breakage (ki) value increase, as feed size fraction increases excluded -2+1mm fraction because the mixed ball size is too small to break the bigger particle.

(2) Coarser ball loads (30, 40 mm size) was significant for the particles larger than 0.3 mm. Fine ball loads (20 mm size) was significant for the particles smaller than 0.3 mm. If the better grinding, particle size distribution will be more reasonable, improving the selected indicators. It should be noted that the above operation condition have verified with further industrial.

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