

COMMUNITION CIRCUIT FOR LARGE CONCENTRATOR^①

Liu Wenzheng^②

*Central Engineering & Research Institute for Nonferrous Metallurgical Industry
Beijing 100088, China*

ABSTRACT

This paper provides a summary of the current comminution circuit and its development trend, focusing the discussion on the comminution circuit selection for the No.3 concentrator with 60 000 t/d throughput in the Dexing Copper Mine. Based on the large amount of information and data on autogenous grinding tests and conventional grinding practices in the Dexing Copper Mine, the comparison results for various comminution circuits as well as the author's suggestions for the comminution system are presented.

Key words: comminution circuit, high energy crushing, crushing more and grinding less.
single stage ball milling

1 CURRENT DEVELOPMENT TREND OF CUMMINUTION CIRCUITS

In the construction and operation of nonferrous metal ore processing plants, the comminution system occupies a top figure in capital investment, in energy consumption and in operating costs. Its production section shares a high tonnage of equipment, a large building space and a large labour force for operation and maintenance. In general, the comminution system makes up about 60% of the total capital cost in concentrator equipment, 40–50% of total operating costs and more than 60% of total energy consumption.

Rowland has summed up eight basic comminution circuits used in worldwide mineral industries^[1].

However, only two basic circuits: the

autogenous grinding circuit and the newly developed conventional circuit are more widely used today. The typical autogenous grinding circuit (Fig.1), which is called SABC or ABC circuit has been operated successfully in nonferrous metal concentrators because of its lower capital and operating costs except for its high energy consumption.

The newly developed conventional circuit — the high energy automated crushing-single ball mill circuit, is an innovation in fine crushing-rod milling-ball milling or medium and fine crushing-single stage ball milling. Because of the use of high energy crushers, which have a higher capacity and can produce fine products (P_{80} 6–8mm), the circuit may increase the grinding efficiency and mill throughput and meet the principle of "crushing more and grinding less".

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^②Professor

The conventional fine crushing-single stage ball mill circuits (Fig.2) have played an important role in the large nonferrous metal concentrators around the world. So through the study of high energy crushing-single stage ball milling, the newly developed conventional circuit will have a realistic significance for the improvement of comminution technology in the nonferrous metals industry of China.

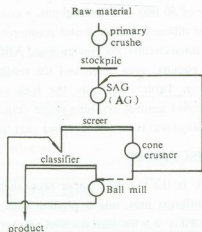


Fig.1 Typical SABC / ABC circuit flowsheet

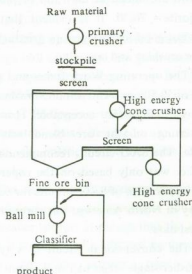


Fig.2 Typical high energy crushing-single stage ball mill circuit flowsheet

However, "there probably never will be any one comminution circuit that will handle properly all ore characteristics and all comminution product specification" [1,3]. So in selecting a specific circuit for each project, different kinds of tests and technical and economic analyses are necessary.

2 COMMINUTION TEST AND PRACTICE IN DEXING COPPER MINE

2.1 Test of Autogenous Grinding Circuit

In 1965, Dexing Copper Mine built its 2 500 t/d concentrator and expanded into 10 000 t/d in 1971. At that time, the first wet, autogenous grinding trial plant with a 2 400 mm (dia.) $\times$ 900 mm (length) autogenous mill was built. This plant has been working for more than 4 600 h and had handled over 9 000 t Dexing copper porphyry ore. In 1979, in cooperation with the staff from Flour Co. USA, large scale AG and SAG tests on different ores were finished. The test results show the followings.

a. Phyllite is not suitable for autogenous or semi-autogenous grinding.

b. Granodiorite, which is more suitable for semi-autogenous grinding, is suitable for autogenous milling too, but it may produce critical particles.

c. Blend ore is suitable for ABC open circuit.

By the end of 1979, the Flour Co. made a comparison between conventional SAG, ABC and AG circuits in its preliminary engineering design for a concentrator of 173 000 t/d. Based on the economic and technical standard in North America, they believed the operating cost of a SAG circuit was at the middle level, the capital cost was the same as that of a

conventional circuit; an ABC circuit had the highest capital cost but the lowest operating cost; the fully autogenous (AG) circuit also had a higher capital cost, but a lower operating cost. So Flour Co. recommended adoption of the SAG circuit.

2.2 Conventional Comminution Practices

No.1 concentrator adopted a conventional comminution circuit of three stage crushing in closed cycle-single stage ball milling (cone crushers-single stage ball mill circuit). Because the initial open pit was near earth surface, the ore contained much clay and moisture. Therefore, a water spray on vibrating screen was installed before a secondary crusher for smooth crushing. However, the single stage ball milling has been proved successful ever since. The unit capacity of the ball-mill is always high and the efficiency is better than that of the same size mill in other concentrators. The operating data are shown in Table 1.

Table 1 Operating data of ball mill of Dexing No.1 concentrator

	3200 × 3100	3200 × 4500
mill size, mm		
mill sets	8	2
mill volume, m ³	22	32
motor power, kW	600	800
ball charge, t	46	65
solid density, wt%	78-80	78-80
feed size(F80), mm	14-15	14-15
feed speed, t/h	52	67
product size (p80, μ m)	119-146	116-120

The calculated operating Work Index of the mill is 13.86, while Bond Work Index measured in lab is 13.61, which are basically equal. It is evident that the ball mill Work Indexes of Dexing ore are less than those of copper porphyry ores and this means that the

Dexing ore is of medium grindability.

According to these views, the No.2 concentrator of 20 000 t/d capacity with a conventional comminution circuit was built in 1982.

3 COMPARISON AND SELECTION OF COMMUNITION CIRCUITS

During the design of the No.3 concentrator of 60 000 t/d throughput, a comparison of different technical and economic data from three circuits, the conventional ABC and SAG circuits, were made and the results are listed in Table 2. Finally the high energy automated control crushing-single stage ball mill circuit was recommended and adopted

4 DISCUSSION

A. In the Dexing Copper Mine there are two different ores, one is phyllite with good crushability, but less feed size and poor grindability; the other is granodiorite which is harder. These two are mined at the ratio of phyllite: granodiorite = 70:30. It is evident that this blend is not good for autogenous grinding, but good for crushing and screening.

B. The operating Work Index and product size of 50:50 ore blend obtained from ABC (no recycle) circuit are acceptable. However, SAG testing on the ore blend was not available. The SAG circuit, recommended by Flour Co. was only based on the experience and the application of SAG circuits for copper porphyry in North America, but without adequate test data.

C. The conventional circuit is a typical cone crusher-single stage ball mill circuit. It is an innovation of the original comminution circuit which embodies the principle of crushing

Table 2 60 000 t / d throughput comminution circuits comparison

	Conventional	ABC	SAG
primary crushing product size, (mm)	250~0	350~0	350~0
primary mill feed size, (F80 mm)	7	180	180
final product size(< 200 mesh%)	65	65	65
Key equipment (unit, mm)	4-second. crushers	4-autogenous mills	4-SAG mills
	SXHD 2 133.6	9 754 × 3 962	9 754 × 4 267
	8-Ter. crushers	—	—
	SXHD 2 133.6	8-ball mills	8-ball mill
	—	5 030 × 8 230	5 030 × 7 925
	4-Double deck vib. screens	6-Ter. crusher	—
	2 438 × 6 096	SXHD 2 133.6	—
	18-single deck vib. screens	6-double deck vib. screens	—
	2 438 × 6 096	2 438 × 6 096	—
	10-ball mills	—	—
	5 029 × 8 839	—	—
equipment weight(t)	8 810	9 090	8 700
installed power(kW)	63 000	65 000	70 000
building space (× 10 ⁴ m ²)	2.9	3.0	2.6
building volume (m ³)	620 000	700 000	580 000
investment of equipment (× 10 ⁵ RMB Yuan / t)	9 700	10 500	9 800
investment of building (× 10 ⁵ RMB Yuan / t)	2 700	2 500	1 800
steel consumption(kg / t)	0.52	0.40	0.58
power consumption(kWh / t)	15.31	18.85	19.25
unit operating cost(RMB Yuan / t)	3.095	3.232	3.501

more and grinding less" and is more profitable in economy. So, this circuit is better than the SAG circuit.

The high energy automated crushing—single stage ball mill circuit has been used in the largest copper concentrators in Bougainville, Papua New Guinea; Seriatu, USA and Atlas Carmen, Philippines. The Dexing No.3 concentrator was designed according to Bougainville practice, since their ores, climates are similar.

The high energy crushing circuit needs high cone crushers and automatic power control crusher motor. It means that the crusher feeder is automatically adjusted by the crusher motor so the crusher may operate continuously at full load, and the whole circuit can reach maximum efficiency.

D. The operating cost varies from place to

place because of the disparity of labour and cost of materials. As indicated in Table 2, the operating costs of ABC and SAG circuits are higher than that of conventional circuits mainly because of the high cost of electricity(0.091 Yuan RMB / kWh, 1983). But an ABC circuit may be preferable to a conventional circuit if the electricity is cheap. This is in agreement with Srinivasa's opinion. He believes that if the power cost reaches as high as \$ 0.045 / kWh, the conventional rod / ball mill grinding circuit will begin to show its advantages^[4].

E. The economic results for the same circuit may be different from region to region, as well as the composition ratio of unit operating costs. For example, the composition ratio of the operating costs of two comminution circuits in the Pima Copper porphyry concentrator is listed in Table 3.

The labour cost for conventional circuit is 21.6% due to more operation and more labour. The material and power consumption for the SAG circuit is higher than that of the conventional circuit, its labour costs account for only 11.9% due to simplified operations and less labour, so the total of this SAG circuit is reduced by 4.7%. However, the labour cost in China is only 3–7% of the total operating costs (5% for the conventional circuit in Dexing Copper Mine). So, it is obvious that the total operating costs of the SAG circuit is still higher than that of the conventional circuit.

(see Table 4)

F. The conventional circuit for ores with a large content of clay-slime can not run smoothly. In this case an AG or SAG circuit has its own advantages. However, ores of varying characteristics and sizes are suitable for conventional circuit as this will cause big fluctuations for AG and SAG circuits and require high level auto-control and skilled management. In this case, if both circuits are basically of same economic benefit, the conventional circuit would be more acceptable.

Table 3. The operating costs of two comminution circuits in Pima

	material	power	labour	others	total
conventional circuit	44.1%	32.4%	21.6%	1.9%	100%
SAG circuit	45.7%	36.4%	11.9%	1.3%	95.3%

Table 4. The operating cost of two comminution circuits in Dexing

	material	power	labour	others	total
conventional circuit	44.1%	32.4%	5%	1.9%	83.4%
SAG circuit	45.7%	36.4%	2.75%	1.3%	86.15%

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