Journal of University of Science and Technology Beijing
1998, Vol.5, No.1: 1

Mineral

Extracting Gold Fines from Pyrite Slag by Hydrophobic Flocculation Flotation

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(Received 1997-10-20)

Abstract: In order to extract gold fines from pyrite slag, the hydrophobic flocculation flotation (HFF) was studied and compared with conventional flotation. The main parameters of HFF such as flotation reagent, surfactant dosage, the duration of agitation and the amount of non-polar oil were investigated, and the effect of non-polar oil was analyzed particularly. It is demonstrated that the HFF is better for gold extraction from pyrite slag than the conventional flotation, and the non-polar oil and the intensive agitation are the key to improve the Au contents and recovery in the concentrate. HFF was used to treat the pyrite slag from the west of Jiangxi province, whose gold contents are 2.94 g/t and the size of which are smaller than 10 μm. The gold concentrate with gold grade 126.3 g/t and 51.35% recovery was obtained. Thus, a new method of extracting gold fines from pyrite slag is developed using HFF.

Key words: pyrite slag; hydrophobic flocculation flotation; gold

It is often encountered that pyrite concentrate contains gold fines, which are difficult to be recovered by the conventional beneficiation methods in the concentrators. The pyrite concentrate is sent to sulfuric acid factory, after roasting all the gold fines are left in the pyrite slag, especially concentrated in the wet slag collected from the smoke pipe line. Therefore, it is beneficial to extract gold from pyrite slag.

Cyanidation is commonly used for gold extraction from the pyrite slag, but the results of cyanidation are usually unsatisfactory due to the co-existing elements such as Cu, Fe, Fe, Ni, Zn[1,2]. The froth flotation is also tested for gold extraction from the slag. It has been reported[3~5] that a gold concentrate with 68.88 g/t contents and 48.68 % recovery was obtained from the pyrite slag with a grade of 1.6 g/t Au by flotation. The flotation circuit consists of rough flotation and 3 steps of cleaning flotation. Another study reported that a gold concentrate with Au 13.04 g/t and recovery 66.46 % was obtained using flotation method. The raw material is pyrite slag which contains 3.04 g/t from Shuikoushan mine. It is obvious that gold extraction by flotation method is not satisfactory.

In the west of Jiangxi province, most gold-bearing chalcopyrite and pyrite is separated by preferential copper flotation, the majority of gold is concentrated into copper concentrate, but there is still some gold left in the flotation tailing—the pyrite product. After the pyrite is roasted for H_2SO_4, the gold content in its pyrite slag is 3 ~ 4 g/t. Cyanidation has been used for gold extraction, but the Au leaching percentage is poor, only 20% ~ 30% and the cyanide dosage is very big. While using conventional flotation, the grade of gold concentrate is only 10 ~ 20 g/t, and the recovery of gold is less than 40%. Because no satisfactory methods have been found, the pyrite slag has to be stored up, occupying a large area of farming land, and causing environmental pollution. It is imperative to find an economical and efficient way to extract gold from the pyrite slag.

The main reason of the inefficiency of the conventional flotation is the extremely fine size of gold particles in the pyrite slag. According to the size analysis, the size of gold particles in the slag is smaller than 10 μm. It is well known that the lowest size limit for the conventional flotation is about 5 μm.

In order to improve gold extraction, new effective technique must be developed for extracting gold fines from pyrite slag. The hydrophobic flocculation flotation (HFF) is one of the most effective way to process fine mineral particles, and it was reported that the good results have been achieved in separation of finely disseminated iron ore, bauxite and other fine minerals[6~8]. Therefore the method of HFF has been chosen for testing.

1 Hydrophobic Flocculation Flotation

HFF consists of 4 key steps: dispersion, hydrophobication, aggregate formation, aggregate flotation. Its schematic diagram is shown in Fig. 1.

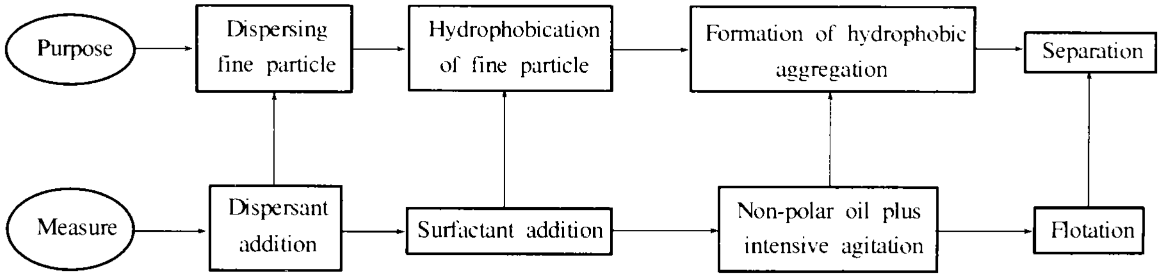

Fig. 1 The process of hydrophobic flocculation flotation

The aim of dispersion step is to prevent heterocoagulation and eliminate the particles coating phenomenon; the second step is to make the fine particles hydrophobic selectively by proper surfactant addition; the hydrophobic particles have tendency to gather together and form firm aggregates with helps of non-polar oil addition and intensive agitation; after the hydrophobic aggregate having formed the conventional flotation can be used to collect the aggregates from the dispersed fine particles.

So we can see that the essence of HFF is to take proper measures to enlarge the apparent size of fine particles to make them suitable for the conventional flotation processing.

2 Sample and Experimental Method

The pyrite slag for this study was taken from Yangjishan mine in the west of Jiangxi province. The composition of the slag (mass fraction, %) are as follow: goethite, 34.66; magnetite, 39.15; hematite, 2.68; chalcopyrite, 3.10; pyrite, 1.77; quartz, 17.91; etc., and the gold content in the slag is 2.94 g/t.

In the pyrite slag, the mass fraction of particles whose grain sizes are smaller than 200 mesh size is 76.75 %. The gold exists in form of natural gold, and the gold particle size is smaller than 0.010 mm.

The reagents used in the experiments of conventional flotation and HFF are kerosene, sodium sulfide, butyl aerofloat ammonium, butyl xanthate and lime. The flotation tests were undertaken with 300 ml laboratory flotation cell. The predispersion was carried out in a agitated tank with an impeller whose rotation speed is adjustable. Before added into the pulp, kerosene was emulsified by the ultrasonic emulsifier.

The gold extraction tests were parallelly carried out using conventional flotation and HFF for comparison. The gold contents was analyzed with Atom Absorption Spectrometry.

(1) Conventional flotation

The main parameters of conventional flotation such as grinding time, collector and modifier selection reagent dosage and pH value were studied. The optimum parameters of flotation have been found, which are 30 min grinding, 200 g/t for the dosage of butyl aerofloat ammonium and butyl xanthate respectively, 300 g/t for the dosage of sodium sulfide, and pH 9. Under these conditions of flotation, the gold concentrate with 12.05 g/t gold contents and 63.87 % recovery was obtained.

The optimum parameters of flotation mentioned above are the conditions for obtaining the maximum hydrophobicity. Thus, these parameters can be also used as the basic conditions for HFF tests of gold particles.

(2) HFF

In addition to the basic flotation conditions, two essential factors for HFF were studied in detail, they are the adding amount of non-polar oil and the duration of mechanical agitation.

(a) Dosage of kerosene

The effect of non-polar oil on gold extraction is shown in Fig. 2 and Fig. 3. The duration of agitation is 15 min.

Kerosene and water mixture with the mass ratio of 1 : 100 was emulsified with ultrasonic emulsifier, and then the emulsion was put into the mineral pulp under intensive agitation. After agitation the pulp was moved into the flotation cell for flotation. The flotation time is 5 min. Because HFF can abate or eliminate the effect of slime, the pyrite samples ground 30 and 50 min were test respectively.

It can be seen from these charts that the gold grade and recovery rate reach 14.48 g/t and 65.37 % respectively. A marked improvement of gold extraction has been achieved compared to conventional flotation.

(b) Duration of agitation

The effect of agitation duration on gold extraction was studied under the optimum dosage of kerosene and the result is shown in Fig. 4. It can be seen from Fig. 4 that the longer the duration of agitation, the

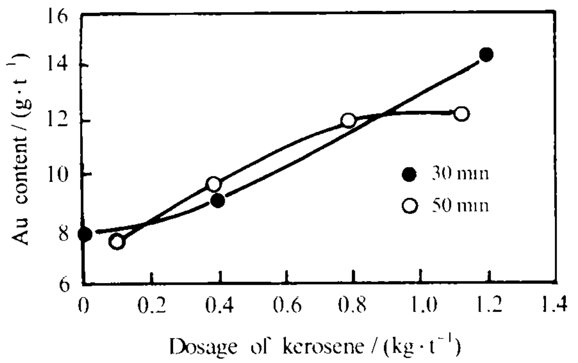

Fig. 2 The effect of dosage of kerosene on Au content

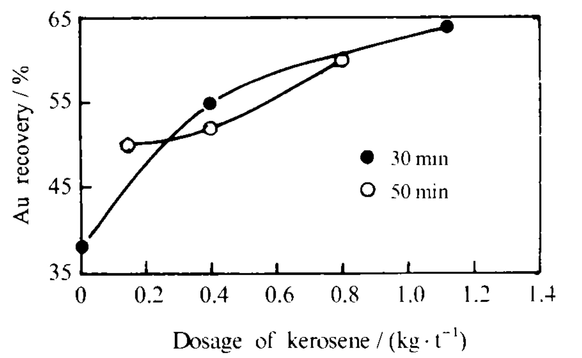

Fig. 3 The effect of dosage of kerosene on Au recovery

better the results of gold extraction. But beyond 15~20 min agitation, the tendency of improving gold extraction become slow. It is proper to chose 20min agitation. Under this agitation duration the gold grade and recovery of gold are 14.40 g/t and 72.34% respectively.

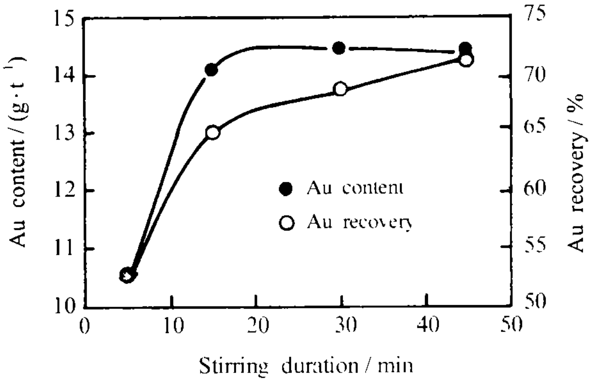

Fig. 4 The effect of stirring duration

3 Functions of Non-polar Oil on Hydrophobic Flocculation

Generally, the non-polar oil has two functions on hydrophobic flocculation, one is that oil droplets can collide with the hydrophobic mineral particles having strong tendency to adhere and extend on the hydrophobic surface of particle, thus the hydrophobicity of the mineral particles is increased; the other is that when the non-polar oil dosage is greater, the oil droplets adhered on the particle surface can form oil bridge between the particles. Thus the intensity of aggregation can be further enhanced.

The emulsion extent of non-polar oil have great influence on hydrophobic aggregate. The effect of emulsion extent induced by different emulsifying time on aggregate is shown in Fig. 5. With the increasing of duration of emulsification, the effect of non-polar oil on the gold extraction is improved and reaches its equilibrium value after 15min emulsification.

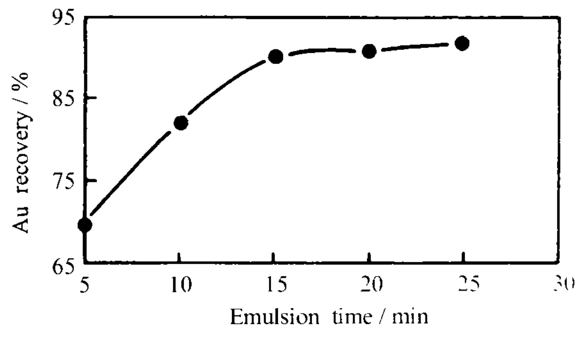

Fig. 5 The effect of emulsion time on agglomeration

Size distribution of oil droplets produced under different emulsifying time is shown in Fig. 6. By 10 min emulsification, the non-polar oil has been completely emulsified and the average size of the oil droplets is 1.29 μm. When the duration of emulsification was 15 min, the average size of the oil droplets was decreased to 0.98 μm, and the oil emulsion becomes more homogeneous as shown in Fig. 5. The gold extraction is further improved.

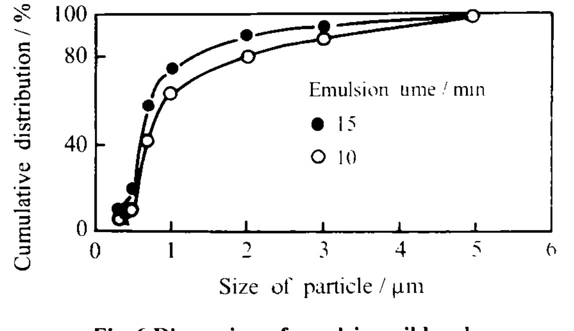

Fig. 6 Dispersion of emulsion oil bead

4 Comparison between Conventional Flotation and HFF

The open circuit experiments of one rough and two cleaning flotation were carried out at the optimum parameters of conventional flotation and HFF respectively. The principle flowsheet of conventional flotation and the HFF are shown in Fig. 7. Their results are listed in Table 1.

It can be seen that the gold extraction using HFF is much better than that of the conventional flotation. In the case of HFF the gold contents and recovery rate are 126.3 g/t and 51.35% respectively, and the concentration ratio is 43. It is reasonable to expect a further

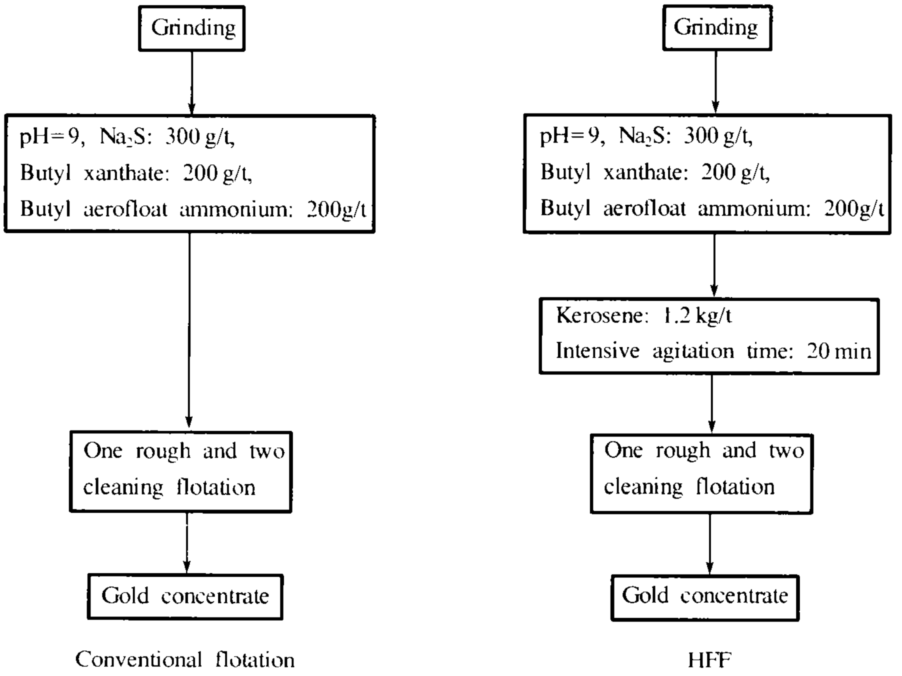

Fig. 7 The principle flowsheet of conventional flotation and HFF

Table 1 The comparison between conventional flotation and HFF

Method	Recovery / %	Concentrate / $(g \cdot t^{-1})$
Conventional flotation	33.60	44.00
HFF	51.35	126.30

increased gold recovery with a closed circuit of HFF.

5 Conclusions

(1) The particle size of the gold in the pyrite slag is so fine that conventional flotation can not extract gold from the pyrite slag efficiently. The hydrophobic flocculation flotation can do so efficiently and by the open circuit of one rough and two cleaning flotation, the gold concentrate of 126.3 g/t Au contents with 51.35% Au recovery was gotten. All of these are satisfactory .

(2) The non-polar oil intensify the hydrophobic flocculation. At one hand, it enhances the hydrophobicity of the surface of particles, and make it easy to form the hydrophobic flocculation; at the other hand, between the particles it forms the oil bridges which increase the intensity and size of the hydrophobic aggregate. Improving the homogeneity of the non-polar oil emulsion can intensify the action of non-polar oil.

(3) The key of extracting gold from pyrite slag by flota-tion is to enlarge the apparent particle size of the gold, and the hydrophobic flocculation is one efficacy measure to reach it. One economical and efficient way of extracting fine gold from the pyrite slag has been developed by the hydrophobic flocculation flotation

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