APPLICATION OF COAL GOLD AGGLOMERATION PROCESS TO GOLD RECOVERING FROM AMALGAMATION TAILINGS[①]

Zhao Bing, Lu Lizhu, Xie Huiqing
Institute of Chemical Metallurgy,
Chinese Academy of Sciences, Beijing 100080

ABSTRACT In gold recovering processes, coal gold agglomeration (CGA) is a novel process which has many advantages compared with conventional CIP/CIL, such as better environmental protection, lower operation and capital cost. The study on gold recovering from amalgamation tailings by CGA process showed that about 88% gold can be captured by coal-oil agglomerates(COA) and the gross gold recovery is more than 85%. CGA process can be applied for extracting gold from hard(rock) ore, alluvial ore, and other gold bearing ores, which are difficult for cyanide processes because of high copper or arsenic content and difficult for gravity process because of small gold particle size, and certain refractory gold ores as well.

Key words CGA process amalgamation tailings gold recovering

1 INTRODUCTION

After the crushed gold bearing ores have been passed through the ball mill, many gold particles can be liberated or exposed from the gangue mineral. When the gold particles and the other minerals associated with them become hydrophobic by means of pH modification, addition of collectors, depressants and activators, coal-oil-agglomerate (COA) can easily capture the oleophilic gold particles and the other minerals associated with them. The COA then is burnt and the resultant residue is smelt to produce gold bullion or extracted by hydrometallurgical method to produce purer gold product[1, 3]. The coal gold agglomeration (CGA) process is a novel gold recovering technique[1], which has following advantages: (1) The gold particles from the fine(minus 5 μm) to the coarse (plus 300 μm) can be recovered effectively; (2) The short residence time and low reagent consumption lead to a low capital and operation cost comparing with traditional CIP/CIL processes; (3) The high selectivity can be achieved against gangue sulphide minerals by depressants and pH modification, as in froth flotation; (4) No cyanide or mercury is needed, therefore the process has good environmental protection; (5) Silver and platinum group metals can also be recovered.

CGA process can be applied for extracting gold from hard(rock) ores, alluvial ores, and other gold bearing ores which are either difficult for cyanide processes because of high copper or arsenic content or difficult for gravity process because of small gold particle size, and certain refractory gold ores. However, it has been proved not suitable for the ore whose gold is extremely fine(< 1 μm), or lateritic ores. When the chief gold bearing minerals are sulphides, such as pyrite, yellow arsenic, *etc.*, although the gold recovery is high, the consumption of coal-oil-agglomerate(COA) would be too high for the process to be economic.

The works carried out in Institute of Chemical Metallurgy indicated that the CGA process can recover gold effectively from many kinds of gold bearing minerals and can be operated successfully in commercial scale[2-5].

① Received Feb. 3, 1997; accepted Mar. 31, 1997

2 EXPERIMENTAL

2.1 Raw materials

The stock is amalgamation tailings in which about 50 samples were collected from individual production sites. The chemical composition of integrated samples is shown in Table 1.

Table 1 The chemical composition of raw materials

Au/g·t^{-1}	Ag/g·t^{-1}	Cu/%	Fe/%	Pb/%
5.04	84	0.80	4.25	1.83
Zn/%	**Ca/%**	**Mg/%**	**As/%**	**S/%**
0.099	0.77	0.69	0.056	0.5

The metallic minerals in the stock are limonite, hematite, gold, gold-silver alloy and some pyrite, galena, chalopyrite *etc*. The non-metallic minerals are calcite, feldspar *etc*. Most of gold particles are between 0.053mm and 0.01 mm and connected with gangues. The collectors are sodium xanthate, ROCSSNa(Y), that is one kind of hydrocarbyl dithio-carbonate, and $(C_4H_9O)_2PSSNH_4$(B), one kind of hydrocarbyl ditho-phosphate.

2.2 Experimental procedure

The COA was prepared by mixing coal powders and diesel oil. The particle size of coal powder is from minus 0.149 mm to plus 0.074 mm. The dosage of diesel oil is 15% ~ 30% (in mass) in COA.

The milled ore was weighed and put into the adhesion tank, then addition of water in a mass ratio(L/S) of 2.5/1.0 was followed. After the pH of pulp was adjusted to proper value by addition of sodium carbonate and sodium silicate, collectors were added successively and respectively. After the pulp was stirred for 15 minutes, the COA was put into the tank and mixed. The separation of COA from pulp was performed by filtration and froth flotation. The COA was recycled to CGA process until saturation. After adding flocculant, the residual pulp was filtered. The filter cake was dried and sample for analysis was taken from.

3 RESULTS AND DISCUSSIONS

3.1 Effects of technological factors on gold recovery

The technological factors, such as ground size of ore, pH value of pulp, the time of adhesion, the amount of the collectors and COA, the stirring strength, affect the gold recovery.

3.1.1 Effect of the ground size of the ore

Since the gold particles are very fine, proper ground size of the ore powder is important for liberation and exposition of the gold particles from the inclusion gangue. But excessive small ore ground not only increase the operation cost, but also cause the surface pollution of gold particles. Table 2 shows the effect of ground size of the ore.

Table 2 Effect of ground size on adhesion

Ground size of < 0.074mm portion /%	40	60	80	90	95	100
Gold recovery/%	44.9	63.7	78.1	86.4	88.5	88.1

Experimental conditions: L/S= 2.5; pH= 9.0; C(Y) = 150g/t; C(B) = 100g/t; C(COA) = 250kg/t; 45min; 800r/min.
where Y —ROCSSNa, B —$(C_4H_9O)_2P$ SSNH$_4$.

It is obvious that the gold recovery increases with the ground size becoming small. When 95% of the ore is milled to < 0.074mm, the adhesion of gold is 88.5%. Further grinding does not increase the gold recovery apparently.

3.1.2 Effect of pH value of pulp

The pH value of pulp affects not only the electrical properties of the mineral particle surface, but also the formation of hydrophobic film on the surface. These two aspects are related directly to the ability of gold particle captured by COA from pulp[2]. The results are shown in Table 3. The tests indicate that although sodium carbonate is a pH adjustor of the pulp, it also can prevent very fine slime coagulation and improve its hydrophilicity.

When pH is less than 7.0 in the pulp, the sodium xanthate can be decomposed. It is obvious that only as the pH value of the pulp is kept higher than 7, $ROCSS^-$ can be stabilized in

Table 3 Effect of the pH value of the pulp

pH	5.0	6.0	7.0	8.0	9.0	10.0
Gold recovery/ %	64.6	72.0	78.6	84.8	88.2	86.5

Experimental conditions: ground size, < 0.074mm 90%; L/S= 2.5; C(Y) = 150g/t; C(B) = 100g/t; C(COA) = 250kg/t; 45min; 800r/min.

pulp. In the test, the favorable pH is about 9.

3.1.3 Effect of the adhesion time

The speed of gold recovery in CGA process is extremely rapid and keeps constant with time. The results are shown in Table 4. In general, the gold particles adhered to COA are more and more with increasing the contact time. However, the increment trend of the gold recovery slowed down quickly. After 45 minutes, the gold recovery kept unchangeable.

Table 4 Effect of adhesion time

Time / min	5	10	15	25	45	60
Gold recovery/ %	78.2	84.3	86.8	87.9	88.5	88.7

Experimental conditions: ground size, < 0.074 mm 90%; L/S= 2.5; pH= 9.0; C(Y) = 150g/t; C(B) = 100g/t; C(COA) = 250kg/t; 800r/min.

3.1.4 Effect of the amount of the collectors

Provided that the gold particles are hydrophobic, they can be captured by COA. The ROCSSNa(Y) and $(C_4H_9O)_2PSSNH_4$(B) can form a hydrophobic film on the particle surface. The experiments show that the mixture of sodium xanthate, Y and B, can increase the gold recovery. The results are shown in Table 5.

3.1.5 Effect of the quantity of COA

Table 5 Effect of the dosage of the collectors

Dosage/ g·t^{-1}	150Y	300Y	150Y+ 100B	150Y+ 50B
Gold recovery/ %	82.5	83.5	88.3	87.8

Experimental conditions: ground size, < 0.074 mm 90%; L/S= 2.5; pH= 9.0; C(COA) = 250 kg/t; 45 min; 800r/min.

It is known from the principle of CGA process that besides the hydrophobicity of gold particle and ability of COA catching gold particles, the contacting probability between COA and gold particles is also an important factor determined partly by concentration of COA in pulp. However, there is a limitation for the concentration of COA, above this critical concentration, gold recovery can not be increased and the loss of COA increases. Furthermore, the saturation time of COA was prolonged and the ability of COA catching gold particle is decreased. In the experiments, the proper quantity of COA is 250kg per tone ore. The results are shown in Table 6.

3.1.6 Effect of stirring strength

According to Liu′s studies[4], in pulp, there are at least three interactions between gold particles and COA particles, the first is Van der Waals force, the second is electrostatic force, the last is hydrophobic force which includes long distance hydrophobic force and hydrophobic associating energy. In any case, the effective contact between gold and COA particles is necessary for COA to offer the dynamic energy for overcoming energy barrier and to catch gold particle. Although high stirring power can increase the probability of contact between gold particles and COA, the gold particles adhered to COA can be dissociated because of high fluid shear force, therefore the stirring speed must be optimized. The results are shown in Table 7.

3.2 Extraction of gold from CGA

The non-saturated CGA is burnt in the ele-

Table 6 Effect of COA quantity

COA quantity / kg·t^{-1}	50	100	200	300	500
Gold recovery/ %	78.0	84.6	87.8	88.0	88.2

Experimental conditions: ground size, < 0.074 mm 90%; L/S= 2.5; C(Y) = 150g/t; C(B) = 100g/t; pH = 9.0; 45min; 800r/min.

Table 7 Effect of stirring strength

Stirring speed / r·min^{-1}	400	500	600	700	800	900	1000
Gold recovery/ %	62.9	70.3	78.1	84.4	88.0	88.1	87.5

Experimental conditions: ground size, < 0.074mm 90%; L/S= 2.5; pH= 9.0; C(Y) = 150g/t; C(B) = 100g/t; C(COA) = 250kg/t; 45min.

ctric furnace at 550~ 650 ℃. The analytical results of resultant residue are shown in Table 8.

The resultant residue is washed by 2 mol/L chlorhydric solution and leached by chlorination[6]. The leaching conditions are as following: L/S= 3.0, NaClO 8.5%, NaCl 5%, HCl 10%, H_2SO_4 4%, time 4 h. The filtered and washing auric solution was adjusted to proper pH value($[H^+] < 0.7$ mol/L), then reduced by Na_2SO_3. The coarse gold powder is refined conventionally at 1 250 ℃. The results are shown in Table 9.

Table 8 Analytical results of residue

COA assay / $g \cdot t^{-1}$	Residue assay / $g \cdot t^{-1}$	Residue mass / %	Recovery / %	Concentrated ratio
456	3 042	15	99.5	604

Table 9 Gold recovery in chief steps(%)

Adhesion	Burning	Washing & leaching	Reduction	Refining	Gross recovery
88	99.5	99.0	99.5	99.5	85.7

3.3 Comparison of CGA process with other gold recovering processes

In order to evaluate CGA process in recovering gold from experimental gold bearing ores, it was compared with froth flotation, chlorination process and cyanidation process. In all tests, gold is 5.04 g/t, L/S is 3.0 and ground size of < 0.074 mm portion is 90%, other conditions are shown in Table 10 and the results are shown in Table 11. It is obvious that the gold recovery of CGA process is higher than that of froth flotation process, close to that of the chlorination process and less than that of cyanidation process. Because of higher copper content, the cyanide consumption is too high to be economic. In the economic and technological points, CGA process is suitable for recovering gold from experimental raw materials.

Table 10 Conditions of control experiments

CGA process	Froth flotation	Chlorination process	Cyanidation process
pH= 9.0	pH= 8.0	NaClO: 8.5%	pH= 10.5
Y= 150 g/t B= 100 g/t	Y= 200 g/t B= 100 g/t	H_2SO_4: 4%	NaCN: 8 kg/t
COA= 250 kg/t	Frother: 50 g/t	NaCl: 5%	24 h
45 min 800 r/min		HCl: 10% 8 h	

Table 11 Comparison of CGA process with other gold recovering processes

Processes	CGA	Froth flotation	Chlorination	Cyanidation
Recovery / %	88.5	82.0	87.8	90.2

4 CONCLUSION

In the experiments, when CGA process is applied to extracting gold from amalgamation tailings, the adhesion recovery of gold is more than 88%, the gross gold recovery is more than 85%. Because no cyanide and mercury are used, the CGA process is good in environmental protection.

REFERENCES

1 Zhao Bing *et al*. Gold, (in Chinese), 1994, 15(5): 27- 30.

2 Jilin Institute of Metallurgy. Gold Ore Dressing, (in Chinese). Beijing: Metallurgical Industry Press, 1988: 45- 61.

3 House C L *et al*. International Mining, 1988, 5(9): 17- 19.

4 Liu Jianjun *et al*. Gold, (in Chinese), 1990, 11 (10): 31- 37.

5 Lu Lizhu, Zhao Bing *et al*. CN ZL92241266. 9, 1992.

6 Liaoning Institute of Metallurgy. Nonferrous Metals: dressing and smeltering, (in Chinese), 1976, (8): 21- 25.

(Edited by Yuan Saiqian)