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Effect of mechanical activation on thiosulfate leaching of gold from complex sulfide concentrate

Mohsen HASHEMZADEHFINI[1], Jana FICERIOVÁ[2], Emad ABKHOSHK[3], Behrouz Karimi SHAHRAKI[1]

1. Iran Mineral Processing Research Center, Karaj, Iran;
2. Institute of Geotechnics of Slovak Academy of Sciences, Watsonova 4504353 Košice, Slovakia;
3. Department of Mining Engineering, Science and Research Branch, Islamic Azad University, Tehran, Iran

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Abstract: The use of mechanical activation to enhance gold recovery from a CuPbZn complex sulfide concentrate was investigated. The effects of milling time, ball size, sample to ball ratio and milling speed on thiosulfate leaching were studied. Under optimum conditions of milling time 1 h, ball size 20 mm, sample to ball ratio 1/15 and mill speed 600 r/min, nearly 78% of sample is amorphized, particle size decreases from d_{100}=30 μm to d_{100}=8 μm, specific surface area increases from 1.3 m^2/g to 4.6 m^2/g and gold recovery enhances from 17.4 % in non-activated sample to 73.26 %.

Key words: mechanical activation; thiosulfate leaching; refractory ore; extraction of gold

1 Introduction

Dissolution of gold from raw materials is mainly performed using cyanide leaching [1], though at present interest in the use of noncyanide processes for recovery of gold is a target due to the increasing concern regarding the hazardous character of cyanide. Thus, several leachants for gold recovery based on the stability of the corresponding gold complexes such as thiosulfate, thiourea, chloride, thiocyanate, ferric chloride and bromide have been proposed. Among them, ammoniacal thiosulphate leaching is considered a promising and nontoxic alternative to cyanidation [2]. The thiosulphate leaching and recovery of gold have been reviewed [2]. With depletion of the oxidized free-milling gold reserves close to the earth surface, most of the important new deposits being mined today do not respond to direct leaching. It is found that the gold is very finely disseminated and encapsulated in host matrices that are inert and/or impermeable to the leaching solution. In many cases, the host matrices are sulfide minerals, which exhibit a strong association with finely disseminated gold particles in many ore bodies [3]. Several attempts have been made to process efficiently those raw materials [4−9].

In order to overcome the refractory character, a pre-treatment is required to breakdown the sulfide matrix and renders the gold amenable for recovery prior to the application of any conventional treatment. The traditional route to treat these types of raw materials is by oxidative roasting of the sulfides before leaching. Alternative viable methods of oxidation such as pressure oxidation, bio-oxidation and electrooxidation have been developed to eliminate pollution problems caused by the emission of toxic gases (SO_2 and As_2O_3) during oxidative roasting [10].

The relatively new process of mechanochemical pretreatment is being successfully applied in both fundamental research and plant operations [11]. In this process, which is also called mechanical activation, the minerals are subjected to high-intensity grinding. This grinding results in particle size reduction and causes chemical or physicochemical transformations, which significantly affect the subsequent hydrometallurgical process [12−17].

Currently, mechanical activation has been widely applied to the pretreatment of minerals [18−21]. Several investigators studied the effect of mechanical activation on sulfide minerals dissolution [22−26]. Many researchers studied the effect of mechanical activation on the extraction of metals in refractory

Corresponding author: Mohsen HASHEMZADEHFINI; Tel: +98-9376715705, Fax: +98-2619208360; E-mail: hashemzadehmohsen@gmail.com
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minerals [27−28], which indicated that mechanical activation can efficiently accelerate the process of hydrometallurgical extraction. FICERIOVÁ et al [29−30] investigated the effect of mechanical activation on gold recovery by thiosulfate leaching from refractory ores and showed that mechanical activation enhanced the gold recovery.

The aim of this work was to investigate the effect of mechanical activation by planetary mill on thiosulfate leaching of the gold from complex sulfide concentrate.

2 Experimental

2.1 Materials

The CuPbZn concentrate was received from the North of Iran. The as-received concentrate after blending was rifled and the samples were collected for chemical analysis, size distribution and mineralogical characterization. Fire assay indicated that the concentrate contained 46 g/t gold. Chemical compositions of the concentrate shown in Table 1 were analysed by atomic absorption spectrometry (Varian 55B, Australia).

Table 1 Chemical compositions of studied concentrate

Element	Content
Pb	4.2%
Zn	7.4%
Cu	1.2%
Au	46 g/t
Ag	255 g/t

The XRF analysis of the concentrate was carried out (Philips magix Pro. 2002, Netherland). The results shown in Table 2 illustrate that the majority of sample is made up of Fe and S which shows the presence of pyrite as a main mineral.

Table 2 XRF analysis of concentrate

Element	Content/%
Al	0.18
Si	2.61
S	43.5
Fe	33.4
Cu	1.4
Zn	8
Pb	4.6

Mineralogical determinations were performed using X-ray diffraction (X'Pert, Philips, Netherland), EPMA (CAMECA SX100, France) and diagnostic leaching (series of acid leaching stages aimed to destroy specific minerals, followed by thiosulfate leaching of the residue from each stage).

Semi-quantitative X-ray diffraction analysis shown in Table 3 and Fig. 1, showed that pyrite and sphalerite are the major minerals, and chalcopyrite, galena, quartz, anglesite, barite and calcite are the minor ones.

Table 3 XRD analysis of concentrate

Mineral	Formula	Content/%
Pyrite	FeS_2	70
Sphalerite	ZnS	11
Quartz	SiO_2	6
Barite	$BaSO_4$	3
Galena	PbS	1.5
Lead oxide	PbO	1
Cerusite	$PbCO_3$	1
Chalcopyrite	$CuFeS_2$	2.5
Anglesite	$PbSO_4$	1.5
Calcite	$CaCO_3$	1
Tetrahedrite	$Cu_{12}Sb_4S$	0.5
Muscovite	$KAl_2(AlSi_3O_{10})(F, OH)_2$	0.5
Goethite	Fe_2O_3. H_2O	0.3
Covelite	CuS	0.2
Total		100

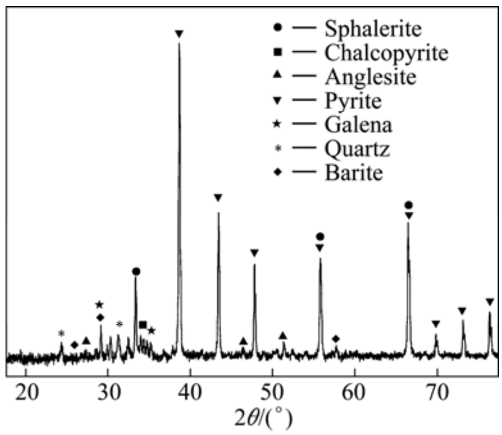

Fig. 1 X-ray diffraction pattern of as-received concentrate

EPMA analysis and diagnostic leaching showed that 82.6 % of gold occurred as invisible gold (solid solution) in sphalerite and 17.4 % of that as free milling filling up the intergrain space of sulfides and quartz. Table 4 shows the average values of 10 points of chalcopyrite, sphalerite, pyrite and sulphosalt minerals carried out by EPMA analyzer. It demonstrates that gold is associated with sphalerite. Figure 2, taken by EPMA, illustrates that free gold (2−25 μm) links to the pyrite, sphalerite and quartz minerals. The diagnostic leaching conditions were beyond of the scope of this work.

Prior to using mechanical activation, the as-received concentrate was ground to 100% passing 30 μm by rod mill. Screen analysis of as-received concentrate shown in Fig. 3 was performed by mechanically shaken Tyler sieves.

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