International Journal of Mineral Processing 142 (2015) 134–138

Contents lists available at ScienceDirect

International Journal of Mineral Processing

journal homepage: www.elsevier.com/locate/ijminpro

Development of a large industrial bio-oxidation reactor in hydrometallurgy

Shen Zhengchang, Dong Ganguo *, Chen Qiang, Han Zhibin

State Key Laboratory of Mineral Processing Science and Technology, Beijing General Research Institute of Mining and Metallurgy, Beijing 100160, PR China

ARTICLE INFO

Article history:
Received 4 October 2014
Received in revised form 19 March 2015
Accepted 3 April 2015
Available online 7 April 2015

Keywords:
Biological oxidation
Biological metallurgy
Reactor
Dissolved oxygen

ABSTRACT

In this paper, the characteristics of the bio-oxidation process are investigated and the design principles of an efficient bio-oxidation reactor are proposed based on the large number of laboratory tests. Methods, such as increasing the height of tank to improve dissolved oxygen content and adding affiliate aeration system to reduce the diameter of air bubbles, are taken. The new type bio-oxidation reactor installed with KYZ-B aeration system is designed and manufactured. The metallurgical performance comparison between the new bio-oxidation reactor and the traditional one was taken by industrial test in Hatu gold concentrator in Xinjiang Uygur Autonomous Region in China.

The result of industrial test shows that: under the same feeding and the same content of S, Fe, As in the overflow of two bio-oxidation reactor, the feed rate in slurry of the new reactor was 3.72 m^3 per hour, but he feed rate in slurry of the traditional reactor was 3.23 m^3 per hour. The feed rate of reactor 2# is 15.2% higher than reactor 1#. The cyanide leaching test was taken. The gold leaching rate of the sample taken in the new reactor is 95.53%, while that of the traditional one is 95.09%. The gold leaching rate and the electron microscopy images demonstrate that the new bio-oxidation reactor has higher oxidation efficiency.

1. Introduction

The gold in refractory ores is encapsulated in sulfide minerals such as pyrite, arsenopyrite and pyrrhotite, which prevents the gold from being leached by cyanide (Fraser et al., 1991). The pretreatment is necessary ahead of a conventional cyanide leach. The main pretreatments of gold-bearing sulfide ores in industrial application include roasting, pressure oxidation, biological oxidation, etc. (Iglesias and Carranza, 1994). The bio-oxidation process has many real advantages over alternative refractory processes such as roasting or pressure oxidation. These advantages include environmental friendliness, low operating cost, lower capital cost, improved rates of gold recovery, low levels of skills required for operation and so on (Yang et al., 2006; Sun et al., 2000). Biological oxidation process has been applied to treat refractory gold ores in Fairview Gold Mine in South Africa in the 1980s (Wang et al., 2001). Now dozens of biological oxidation plants are operating in South Africa, China, Brazil, Peru, Chile, American, Mexico and other countries over the world (Morin et al., 2005).

The bio-oxidation process utilizes the bacteria to break down the sulfide mineral matrix thereby liberating the occluded gold for subsequent cyanidation and increasing the overall gold recovery (Nematia et al., 1998). The oxygen consumption during direct sulfide oxidation is high. The large volumes of air have to be injected and dispersed in the slurry. This is one of the main engineering challenges in the design of a full scale bio-oxidation reactor (Dew et al., 1997).

The industrial bio-oxidation reactors in biohydrometallurgy are almost all the mechanical bio-oxidation reactors in the world. In order to keep solid particles in suspension and split the airflow into fine air bubbles, the impeller of the reactor must rotate at a high speed. The evidences presented by Ragusa show that, mechanical shear produced by the impeller may rip off bacteria from mineral particle surfaces, which make unrecoverable damage to the bacteria, and then the oxidation efficiency declines. Breed & Hansford think that the decisive factor in the biological oxidation reactor is oxygen consumption, rather than the total solid concentration. That is to say, more dissolved oxygen content contributes to growth of bacteria. However, it doesn't mean that the more air, the better the oxidation efficiency. The increasing gas volume will enhance the stirring intensity and the corresponding shear stress, which is harmful to bacteria growth. Furthermore, a mass of air may escape from the reactor, which leads to a waste of energy (Breed and Hansford, 1999). In summary, a highly efficient bio-oxidation reactor has features of high mass transfer rate, high dissolved oxygen, low impeller stirring intensity (Liu et al., 2004). It is an engineering problem how to slit the airflow into a mass of fine bubbles and how to make these fine bubbles disperse evenly in the slurry in the lower impeller speed.

* Corresponding author.
E-mail address: dong_gg@bgrimm.com (G. Dong).

http://dx.doi.org/10.1016/j.minpro.2015.04.001
0301-7516/

2. Design of a large industrial bio-oxidation reactor

2.1. Traditional bio-oxidation reactor

The industrial bio-oxidation reactors in biohydrometallurgy are mechanical bio-oxidation reactors. The schematic diagram of the traditional reactor is seen in Fig. 1. The air is injected into the slurry through the pipe ring installed on the reactor tank bottom below the impellor. The air flow will be divided into fine bubbles by the rotating impellor. In order to decrease the damage to the bacteria, the impellor must rotate at a low speed. A mass of air escapes into the atmospheric environment in the form of large bubbles or airflow. The dissolved oxygen content is low, which reduces the oxidation efficiency.

2.2. Design of a new type of the bio-oxidation reactor

The oxygen mass transfer represents the most important parameter implied on the design and operation of the bioreactor (Galactiona et al., 2004). Oxygen mass transfer depends largely upon the total surface area rate and agitation intensity.

KYZ-B sparger is an automatic, self-regulating gas injection system, which is designed and manufactured by BGRIMM (Beijing General Research Institute of Mining & Metallurgy, China). The picture of KYZ-B sparger is shown in Fig. 2.

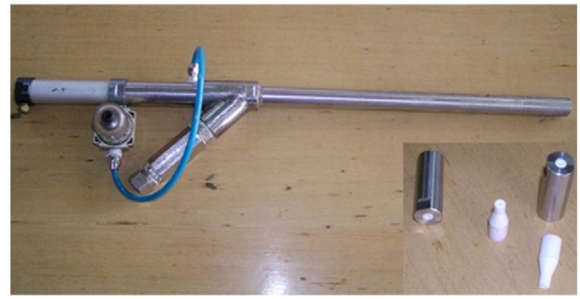

Fig. 2. The picture of KYZ-B sparger.

The KYZ-B sparger has proven to be highly effective in producing the optimally sized bubbles required for maximizing oxygen mass transfer rates, because millions of micro bubbles produced by the sparger ensure rapid transfer of oxygen to the pulp. The picture of the mass of fine bubbles in water produced by KYZ-B sparger is shown in Fig. 3.

A new bio-oxidation reactor is developed, which is 9.5 m in diameter and 10 m in height. The general drawing of a new bio-oxidation reactor installed KYF-B spargers is seen in Fig. 4. The new bio-oxidation reactor mainly consists of tank body, aeration system, agitation system and cooling system. The tank body consists of a round tank, made of AISI 316L, and a supporting beam made of ASTM A36. The agitation system consists of a motor, a reducer, a shaft and two impellers. The impellers are fixed on the shaft. The cooling system consists of six sets of heat exchangers uniformly distributed in the tank, which are made of stainless steel pipe. The parameters of 700 m^3 bio-oxidation reactor is seen in Table 1.

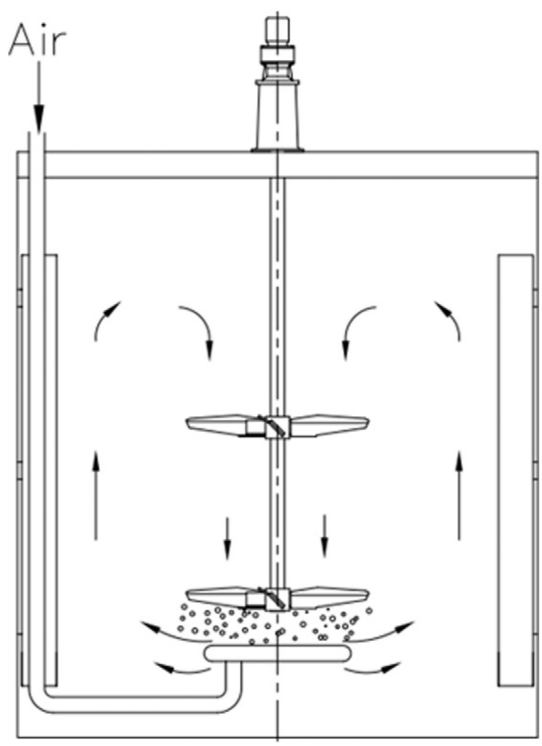

Fig. 1. The schematic diagram of a traditional reactor.

The new bio-oxidation reactor takes 42 KYZ-B spargers as the aeration system. The nozzle diameter of spargers is 5 mm. 42 spargers uniformly distribute along the circumferential direction in the bottom part of tank wall. Every sparger can independently be closed and opened by a manual valve, so it is easy to adjust inject aeration rate. The air is injected into the slurry through the spargers. High speed air flow is cut into a large number of small air bubbles by fluid shear. When the diameter of the air bubble decreases, the gas–liquid interface increases. It is a notable way to improve the dissolved oxygen. The sparger is designed to operate at air pressures ranging up to 0.7 MPa, but typically pressures of 0.3 to 0.6 MPa are used in the field. The high-speed airstream produced by sparger has the function of mixing pulp, so the impeller rotational speed could be cut down.

3. Industrial test of bio-oxidation reactor

3.1. Water test

In order to measure the dissolved oxygen content in bio-oxidation in water, twenty measuring points are chosen in the horizontal section. In the vertical direction, twelve measuring sections are uniformly arranged, which are 0.5 m, 1.0 m, 1.5 m, 2.0 m, 2.5 m, 3 m, 3.5 m, 4 m, 4.5 m, 5.0 m, 5.5 m and 6 m from the tank bottom up. The dissolved oxygen content is measured by Cyber Scanner DO110. Dissolved oxygen data in water are shown in Table 2.

It can be seen from Table 2 that in the same aeration rate, dissolved oxygen content increases with the increasing of depth, and they are basically in linear relationship. Dissolved oxygen content in the tank varies in a small range along with aeration rate, the main reason is that there is

Fig. 3. Fine bubbles in water produced by KYZ-B sparger.