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A significant improvement of foam performance using Pluronic in molybdenum flotation

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ABSTRACT

In present study, a significant improvement of molybdenum recovery was obtained through improving foam performance using Pluronics (L-61 and L-65), which were used as foam conditioner. The solution properties of L-61 and L-65, such as foamability, bulk rheology, and foam stabilities, on the flotation, were investigated through surface tension and rheological measurements. Results showed that the foam performance of fusel/L-65 composite system was better than those of fusel and fusel/L-61. Moreover, it was forever confirmed by bench-scale flotation that the recovery was increased by 5%, indicating that the foam performance could be improved with addition of L-65.

Introduction

Foam properties play a very important role in many industrial processes, such as in flotation processes, pulp and paper, paint and coatings, textile, leather, adhesive, food processing (sugar, yeast, potato), and metal processing, etc. [1–3]. Flotation utilizes the hydrophobic (aerophilic) nature of mineral surfaces and their tendency to attach to rising air bubbles in a water–ore pulp [4]. The hydrophobic particles are concentrated or separated from pulp in the form of the foam selectively due to their adhesion and persistence in the air bubbles rising from pulp [5]. Therefore, the foam plays an indispensable role in all flotation mechanisms.

Jinduicheng Molybdenum Co., Ltd., located in Shanxi Province, is currently holding a largest molybdenum mine in china. This company is using flotation technique for ore processing where diesel is used as a collector, and fusel is used as a frother. However, there are many problems in the industrial production of the mine including slow bubbling, small froth quantity in the rough flotation and the large viscosity of foam. Therefore, the froth is not easy to burst and accumulated in the froth tank, so that the concentrate in the froth surface easily fall off, which make the recovery every low. Many traditional methods have been applied to improve the flotation recovery by changing the frother, collector, and even the depressant, but the experiments were innovative by adding additives that are poor in catchability and foaming to achieve the desired results, and this method was barely mentioned in the published literatures.

Literatures reported that the low-molecular polymers can be adsorbed on the surface of foam to improve its performance by changing the surface viscosity of foam film, and thus this can affect the drainage dynamics and gas permeability [4]. Drainage dynamics are mainly studied in nodes, lamellas and Plateau borders [6]. The rupture of the foam is mostly due to the liquid drainage from the foam film and capillary suction, i.e., the foam stability is highly related to the properties of foam film [7,8]. The boundary conditions at air/liquid interfaces in the foam determined mainly by surface viscoelastic properties of adsorption layers are also of great importance for the drainage kinetics.

Polyoxyethylene–polyoxypropylene–polyoxyethylene triblock copolymers (POE/POP/POE copolymers, Pluronics) are widely used as antifoams and wetting agents in paper industry, water treatment, fermentation or as a component of machine dish washing mixtures and spray cleaners [9]. And these are also used as emulsifiers, stabilizers, solubilizers, absorption enhancers, slow release materials, solid dispersants. However, there is no published literature to describe the application of polyoxyethylene–polyoxypropylene–polyoxyethylene triblock copolymers in the field of mineral processing, which are used to adjust the foam properties during the flotation.

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Table 1
Structure and HLB of the Pluronics copolymers studied.

Pluronics

$HO-(CH_2CH_2O)_x-(CH_2CH(CH_3)O)_y-(CH_2CH_2O)_x-H$

Materials	Average molecular weight (g/mol)	Cloud point (1% aqueous solution)	pH value (1% aqueous solution)	HLB value	X	Y
L-61	2000	17–21	5.0–7.0	3	2.8	30
L-65	3500	75–85	5.0–7.0	15	18	30

Therefore, in current study the frothing speed of frother, rate of bubble attenuation, surface tension, liquid film viscosity and so on were studied in the presence and absence of Pluronic which is used as a conditioner. The encouraging results were obtained from the study which suggest that the recovery can be enhanced by improving the frothing performance in order to reduce the ability to entrain mineral particles and increase the possibility of mineral collision. During the bench-scale flotation tests, the rough flotation recovery of molybdenite was significantly improved, and this excellent performance was further confirmed in the closed-circuit test. This innovative method could be applied efficiently in other flotation systems to improve the comprehensive utilizations of resources.

Materials and methods

Samples

Samples of molybdenum ore were collected from Jinduicheng Molybdenum Industry Co., Ltd., China. Particle size of as received samples were less than 5 mm. The ore was crushed by a jaw crusher and a roller crusher to produce ore particles which were less than 2 mm. After crushing, ore was ground in a ball mill for 100 s to obtain the final material with particle size less than 0.074 mm for fifty-five percent. The final material was prepared for flotation.

Chemical reagents, L-61 and L-65, were received from the Jiangsu Hai'an petrochemical plant, and the molecular structure and specific parameters of these two reagents are shown in Table 1. Fusel is a by-product of a chemical plant. Diesel is supplied by Changsha Guang'en Analytical Instruments Co., Ltd.

The surface tension of deionized water was measured as 73.4–73.6 mN/m.

Methods

Foaming by bubbling

The foam was produced by placing the foaming solution (40 mL) to the bottom of glass column and a constant air flow of 1 L/min was bubbled into the solution through a porous glass plates. The constant air flow was produced by the Model HP-1116 Electromagnetic Vibrating Air Pump (Morrison Group Co., Ltd.), and air flow rate was measured by Model LZB-3WB Glass Rotor Flowmeter (Revitalization). The study was carried out at 25 °C temperature. The foaming time (t_f) is the time required to reach the maximum foam volume. The half-life time, $t_{1/2}$ (the time required for the foam volume decreased to 50% from its maximum volume), was used to characterize the foam stability [10]. The cross-sectional area of the column was 1.1 cm^2 and the column diameter was 1.18 cm.

Surface tension

The surface tension of the aqueous solution of fusel, mixed aqueous solution of fusel and Pluronic was measured by the BZY-2 automatic table/interfacial tension meter produced by the Shanghai Hengping Instrument Factory. The test temperature was set to 25 °C temperature. The mixture was stirred for three minutes to measure the equilibrium surface tension. Each result was the average of the three measurements.

Rheological properties

The rheological characteristics of fusel and fusel/Pluronic aqueous solution were tested on the MCR 102 rheometer with a standard concentric cylinder (CC27) at 25 °C temperature. The dynamic viscoelastic measurements of the aqueous solution were carried out on the MCR 102 rheometer (Anton Paar GmbH, Austria Graz) at 25 °C temperature. The viscosity of the aqueous solution was measured at a frequency of 1 Hz by a shear rate scan (0.1–100 S^{-1}). The viscosity and time isotherms were then obtained at fixed frequency (1 Hz) and shear rate (1 S^{-1}). In the amplitude sweep measurement, the shear strain range was set from 0.1 to 100% to determine the loss modulus and storage modulus of the solution at a frequency of 1 Hz.

Flotation equipment

The bench-scale flotation tests were conducted in a laboratory single cell flotation machine (XFD-1.0 L, XFD-0.5 L) manufactured by Jilin prospecting machinery factory (China).

Flotation experiment

The flotation tests were carried out in the XFD flotation cell with a volume capacity of 1 L and 0.5 L. The 55% of feed samples with particle size less than 0.074 mm was used in tests. The flotation concentration was adjusted to a desired level by using tap water. The pulp concentration (solid%) was adjusted from 55% to 25%, respectively. After that, the required amount of collector was added and pulp was conditioned for 3 min, and the frother was added and conditioned for 3 min. The flotation time was 2 min. The flotation flowsheets of the experiment was shown in Fig. 1. Both the concentrate and tailings were filtered, dried and weighed. Concentrate and tailings were analyzed with XRF for elemental composition.

Results and discussion

Foam experiments

Foaming properties of Pluronic

The effect of pure Pluronic L-61 and L-65 on the maximum foam volume is shown in Fig. 2. It can be seen from Fig. 2 that there is no significant increment in the volume of foam after bubbling when the concentration of L-61 or L-65 is less than 1 mg/L. Furthermore, it is found that the foam volume was increased rapidly when the Pluronic concentration is increased from 1 to 2 mg/L. Results suggest that there is no foaming property at low Pluronic concentrations, therefore addition of Pluronic will not affect the amount of foam.

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