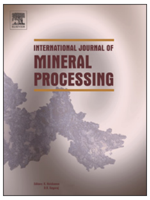
International Journal of Mineral Processing 168 (2017) 1–8

Contents lists available at ScienceDirect

International Journal of Mineral Processing

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



Non-polar oil assisted DDA flotation of quartz I: Interfacial interaction between dodecane oil drop and mineral particle

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ARTICLE INFO

Article history:
Received 3 February 2017
Received in revised form 29 July 2017
Accepted 7 September 2017
Available online 08 September 2017

Keywords:
Quartz
DDA
Dodecane
Interfacial interaction potential energy
EDLVO theory

ABSTRACT

In this paper, in order to study the interaction mechanism of non-polar oil assisted dodecylamine (DDA) flotation of quartz, the particle-oil drops system were treated the same as the hydrophobic particles system. Pure dodecane was chosen as research object, the interfacial interactions between quartz particle and oil drop were investigated through calculation of the extended Derjaguin-Landau-Verwey-Overbeek (EDLVO) potential energy profile. Based on the calculations of the van der Waals attractive interaction potential, hydrophobic interaction potential, hydrocarbon chain association potential, and electrostatic interaction potential, the results indicated that the mineral particle and oil drop attachment state was mainly dominated by hydrophobic interaction potential. In the modification of oil agglomeration flotation process, the adsorption of DDA on the dodecane/water interface presented significant effects on the interfacial interactions between quartz particle and oil drop. It was found that the adsorption of DDA at dodecane/water interface changed the zeta potential value of oil drop from negative to positive. In this case, the attachment of the particles would occur spontaneously, which was due to the contribution of electric double layer attractive interaction. On the contrary, in the traditional oil agglomeration flotation process, a mechanical agitation was required to overcome a potential barrier due to the existence of electric double layer repulsive interaction between the negatively charged oil drops and mineral particles. This study was focus on the theoretical level, and provided some insights into mechanism of oil agglomeration flotation.

1. Introduction

Non-polar oils, such as kerosene, diesel, soybean and rapeseed oil has been widely used as collectors or bridging reagents in the traditional flotation and oil agglomeration flotation process (Pereira, 2003; Rodrigues and Matiolo, 2007; Sadowski and Polowczyk, 2004; Sen et al., 2010; Song et al., 1999; Sis and Chander, 2003; Mehrotra et al., 1983; Araujo et al., 2005). A number of different benefits have been observed resulting from the use of neutral oils as the flotation reagent. Firstly, according to Seitz and Kawatra, the co-adsorption of oil and collector on the mineral surface resulted in the reduction of collector dosage requirement (Seitz and Kawatra, 1986). The non-polar oils are less expensive reagents and considerable cost savings can be achieved. Secondly, the formation oil films on hydrophobic particles increase the degree of hydrophobization and promote aggregation by bridging the particles (Laskowski et al., 1992). Thirdly, it increased the recovery of hydrophobic minerals due to the improvement of air bubble-particle adhension. It can result in a more highly mineralized froth, which drains more easily and it also reduces the initial entrainment of fine hydrophilic gangue by reducing the necessary retention time (Sonmez and Cebeci, 2006).

In the traditional oil agglomeration flotation process, the hydrophobic particles are agglomerated in an aqueous medium by bridging liquid (non-polar oils) which is immiscible with water, whereas the hydrophilic particles remain in the suspension (Sadowski and Polowczyk, 2004; Sonmez and Cebeci, 2003; Fuerstenaua et al., 1979). It is well recognized that the effect of oil drops in oil agglomeration flotation is derived from following two aspects: on the one hand, attachment of oil drops to mineral particles; on the other hand, spreading of oil drops on the surface of hydrophobic particles and formation of oil bridge between mineral particles.

The basic principles of oil agglomeration flotation and effects of various operating parameters have been investigated by many researchers, and the technique has been used in the mineral industry for the purification of many different types of minerals such as naturally hydrophobic coal (Sonmez and Cebeci, 2006), sulfur and molybdenite (Rodrigues and Matiolo, 2007; Song et al., 2012; Fu et al., 2012), hydrophilic oxides zinc ores and hematite (Fu et al., 2012; Pereira, 2003), hydrophilic salt type minerals phosphate ores and silicates mica and feldspar (Sis and Chander, 2003; Fenske, 1956; Malghan, 1976).

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http://dx.doi.org/10.1016/j.minpro.2017.09.004
0301-7516/

Theoretical analysis as well as experimental measurements reveals that the various phases such as oil density and viscosity, oil concentration, flotation medium pH, stirring time and intensity greatly influence the flotation process (Capes and Germania, 1982; Laskowski, 1992; Chary and Dastidar, 2010; Lu et al., 1998; Ozkana et al., 2005). How the interactions between different phases affect the flotation process provides some insights into oil agglomeration flotation. It is well accepted that non-polar oils would not adhere on a hydrophilic surface, and in the traditional oil agglomeration flotation the non-polar oils were added after collector and interacted with previously hydrophobised mineral particles. The interaction affinity of oil drops and mineral particles was mainly dominated by hydrophobic interaction (Dai and Lu, 1991).

In our previous work, a modification of oil agglomeration flotation has been proposed, which is based on introduction of the premixed combination of DDA and kerosene as the collector (Liu et al., 2014; Liu et al., 2016). In this case, DDA cationic reagent would adsorb on kerosene/water interface in advance, the coated on DDA's non-polar oil has well promoted the fine quartz particles agglomeration. This premixed collector addition manner prevail the traditional way. The adsorption model of mineral and premixed collectors (Fig. 1) was proposed through research on surface property of DDA and kerosene emulsion, morphological of fine quartz concentrate and variation of surface potential of quartz (Liu et al., 2014). As mentioned before, the significant step of mineral particle and non-polar oil drop interaction is attachment. Whether the spontaneous attachment would occur depends on the total potential energy of particle and oil drop interaction. However, the interfacial interactions between quartz particles and oil droplets, which plays an important role in the oil flotation agglomeration process, have not been revealed yet in our previous study.

In this paper, in order to investigate the interfacial interactions between quartz particles and oil droplets, pure dodecane was chose as oil component representative to investigate the interfacial interactions between quartz particle and oil drop through calculation of the extended Derjaguin-Landau-Verwey-Overbeek (EDLVO) potential energy profile. Here, the pure dodecane chose as research objects was because kerosene was a mixture of different structure of alkane, olefin and cycloalkane, and it can be expected that it was difficult to calculate the interfacial interactions between these complicated mixture and quartz particle. Furthermore, the interaction of dodecane oil drop and quartz particle can be analogous to other non-polar oil systems for the similar calculation process. The effects of the interaction between dodecane and DDA on the interfacial interactions of the quartz-dodecane system, and the influence to the relationships between hydrophobic attraction and surface properties were further studied. On the basic of viewpoint from energetics aspect, this research provides some valuable insights into mechanism of oil agglomeration flotation, for instance, which force dominates between mineral particles and oil droplet, and how collector adsorption affect interfacial interactions. And in addition, this investigation would aid industrial applications of this traditional technology.

2. Materials and methods

2.1. Samples and reagents

In this work pure quartz (SiO_2) particles was used as mineral sample. The volume median diameter (d_{50}) of the mineral sample was 27.6 μm, and the specific surface area of the samples was 0.38 m^2/g. DDA of analytical purity was obtained from Tianjin Guangfu Chemical Research Institute, and analytically grade dodecane used as non-polar oil was supplied by Aladdin Reagent. HCl and NaOH, both being of analytically grade, were used as the pH modifiers in the zeta potential measurements. The premixed DDA and dodecane was prepared by dissolving different concentrations of DDA in the dodecane and stirred with a magnetic stirrer at 40 °C until a homogeneous sample was obtained.

2.2. Methods

2.2.1. Flotation tests

Flotation tests have been carried out in a XFG-1.5IV flotation machine with 1.5 L cell. The stirring speed was set at 1500 rev/min, pulp density was controlled at 20%, and the temperature of pulp was maintained at 20 °C in natural pH. In the flotation tests, when the premixed DDA and dodecane was used as collector, the premixed collector conditioning time was 2 min; while in the traditional oil agglomeration flotation, dodecane was added after DDA, DDA conditioning time was 2 min, and dodecane conditioning time was 2 min. In the flotation tests, The DDA dosage was consistent 40 g/t, the amounts of dodecane was different, and the specific dosage of dodecane was in Section 3.1. The water used in flotation tests was tap water and its pH was 7.6.

2.2.2. Zeta potential measurements

The zeta potential measurements of mineral particles and oil drop were carried out by using a JS94H micro-electrophoresis apparatus of Powereach. The concentration of 0.3 wt% premixed DDA-dodecane emulsion and pure dodecane emulsion were obtained by agitation lasted for over 30 min at 1500 rev/min with a high speed agitator. This concentration was the proper condition for zeta potential measurement known from our previous study (Liu et al., 2014), and the ambient temperature was controlled at 20 °C. The water used in the zeta

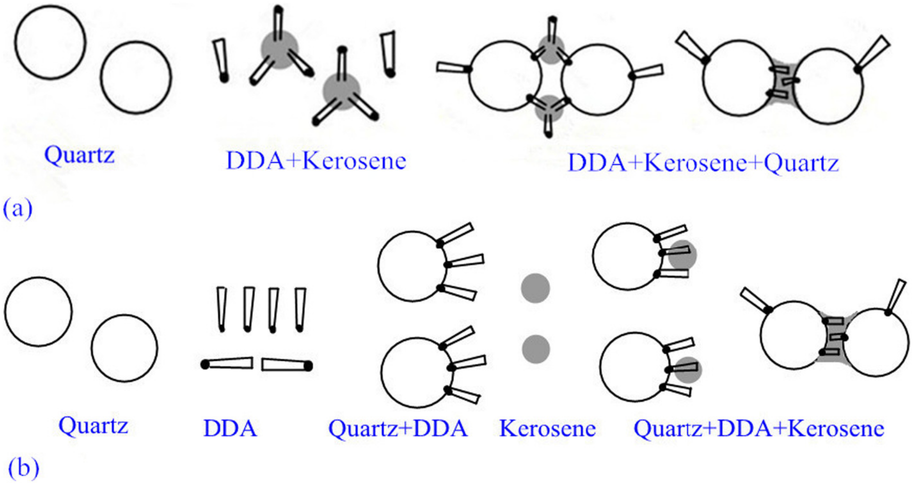

Fig. 1. Schematic representation of the interaction of quartz particle and oil drop, premixed DDA and kerosene emulsion(a), and kerosene emulsion(b).