Minerals Engineering 66–68 (2014) 13–24

Contents lists available at ScienceDirect

Minerals Engineering

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

The effect of saline water on mineral flotation – A critical review

Bo Wang *, Yongjun Peng *

School of Chemical Engineering, The University of Queensland, St. Lucia, Brisbane, QLD 4072, Australia

ARTICLE INFO

Article history:
Received 20 December 2013
Revised 7 April 2014
Accepted 12 April 2014
Available online 6 May 2014

Keywords:
Saline water
Hydration layer
DLVO theory
Bubble coalescence
Particle interaction
Froth stability

ABSTRACT

Due to scarcity of fresh water and stringent regulations on the quality of discharged water, more and more flotation plants have to use groundwater, sea water or recycle water with a high concentration of electrolytes. Although a number of studies have been conducted to investigate the effect of saline water (or salt solutions) on mineral flotation, effective ways to solve the problems encountered in mineral flotation plants using saline water are currently not available. This paper presents a review of published articles addressing the effect of saline water on the interfacial phenomena taking place in the flotation process, such as surface wettability, bubble-particle collision and attachment, mineral particle interactions and frothing. This review provides an overall picture of the current status of studies in this area and pinpoints directions of future research to address different problems associated with using saline water in mineral flotation.

Contents

1. Introduction . . . 14
   1.1. Principles of mineral flotation . . . 14
   1.2. Flotation practice using saline water . . . 15
      1.2.1. Base metal sulphides . . . 15
      1.2.2. Coal . . . 15
      1.2.3. Potash . . . 15
2. Water structure . . . 16
   2.1. Pure water structure . . . 16
   2.2. Saline water structure . . . 16
      2.2.1. Water structure model . . . 16
      2.2.2. Effect of ions on water structure in flotation . . . 16
3. Effect of saline water on particle properties . . . 17
   3.1. Hydration layers on particles . . . 17
   3.2. Electrical double layers around particles . . . 18
      3.2.1. DLVO theory . . . 18
      3.2.2. Wetting film between particles and bubbles . . . 18
      3.2.3. Particle aggregation . . . 20
4. Effect of saline water on bubble properties . . . 20
   4.1. Inhibition of bubble coalescence in salt solutions . . . 20
   4.2. Froth stability . . . 21
5. Conclusions . . . 22
   Acknowledgements . . . 23
   References . . . 23

* Corresponding authors. Tel.: +61 7 3365 7156; fax: +61 7 3365 3888.
E-mail addresses: bo.wang@uq.edu.au (B. Wang), yongjun.peng@uq.edu.au (Y. Peng).

http://dx.doi.org/10.1016/j.mineng.2014.04.017
0892-6875/

Notation

A	Hamaker constant, erg
A_{131}	the complex Hamaker constant between particles 1 separated by medium 3
a	the radius of spherical particles
B	retarded van der Waals coefficient, erg·cm
C	the hydrophobic interaction constant
c	concentration of surfactant, mol/L
c_t	transition salt concentration, mol/L
D_0	the decay length
g	gravitational constant
H	the distance separating the two particles
h	film thickness between coalescing bubbles, m
R	radial coordinate of bubble column, m
R_d	radius of contact area between bubbles
r_b	rubble radius, m
R_g	gas constant
t	coalescence time, s
T	temperature

Greek letters

ε	energy dissipation rate per mass, m^2/s^2
Γ	bubble coalescence rate, $m^{-3}\ s^{-1}$
$\gamma_{s/A}$	the surface energies between solid-air
$\gamma_{s/W}$	the surface energies between solid-water
$\gamma_{W/A}$	the surface energies between water–air
ψ_d	the surface potential,
κ	the reciprocal Debye
ρ	density, kg/m^3
σ	surface tension, kg/s^2
τ	bubble contact time, s
θ^B	buoyancy driven collision rate, $m^{-3}\ s^{-1}$
θ^{LS}	collision rate due to laminar shear, $m^{-3}\ s^{-1}$
θ^T	collision rate due to turbulence, $m^{-3}\ s^{-1}$

Subscripts

b	bubble
f	final
g	gas
i, j	particle i, j
l	liquid

1. Introduction

1.1. Principles of mineral flotation

Mineral flotation which enables the selective separation of fine particulate valuable minerals from waste or gangue minerals exploits the difference in surface wettability of valuable and gangue minerals and is recognised as an effective method for the concentration of valuable minerals. In the practice of mineral flotation, a pulp of solid particles in water is conditioned with a small amount of reagents with air being purged into the pulp to form bubbles that can collide with particles. Collector is normally added to render one mineral (usually the valuable mineral) selectively hydrophobic, while frother is added to help the formation of small bubbles in the pulp and a froth layer on the top.

It is established that the flotation rate constant, k, and the bubble surface area flux, S_b, follow a linear relationship (Grano, 2006):

$$k = \frac{1}{4} S_b E_{coll} \tag{1}$$

where collection efficiency, E_{coll}, refers to the intrinsic efficiency of particles captured by individual bubbles. This term embraces collision, attachment and detachment as sub-processes in the overall collection process as shown in Fig. 1. For a particle to be collected by a bubble it must first collide with the bubble. The collision efficiency (E_c) quantifies the process of collision, and is totally controlled by hydrodynamics in the flotation cell. The particle size and density, bubble size and velocity all affect the value of the collision efficiency. Following collision, only hydrophobic particles tend to attach to the bubbles. The attachment efficiency (E_a) quantifies the process of attachment and is controlled by pulp chemistry and mineral surface chemistry. Collector adsorption, activation and oxidation may produce a mineral surface that is coated with hydrophobic regions, facilitating the attachment of the particle to the bubble. The detachment efficiency (E_d) quantifies the process of detachment. For the bubble-particle aggregate to be transported to the pulp/froth interface at the top of the pulp, it must be stable against detachment by the shear forces operated in the flotation cell. The bubble-particle detachment efficiency is also controlled by the hydrodynamics in the flotation cell and surface hydrophobicity. The sub-processes of collision, attachment and detachment together control the intrinsic collection efficiency (Dai et al., 2000):

$$E_{coll} = E_c \times E_a \times (1 - E_d) \tag{2}$$

Once the particles move from the pulp to the froth, the froth provides a second chance for selective separation of minerals by allowing the drainage of hydrophilic gangue minerals back into the pulp. A metastable froth is a prerequisite for the successful transport of mineral laden bubbles from the pulp/froth interface over the lip of the flotation cell and to the concentrate launders. It is desirable that the mineralised froth breaks down (i.e., the bubbles collapse) once it reports to the concentrate launder. The overall flotation efficiency is governed by the particle recovery in both pulp and froth phases.

Dissolved ions in solutions may alter the water structure, particle surface wettability and colloidal interactions between bubbles and particles and therefore have a positive or negative effect on mineral flotation. Before reviewing the past and recently published articles related to the impact of saline water on interfacial processes in mineral flotation, flotation plants using saline water is summarised.

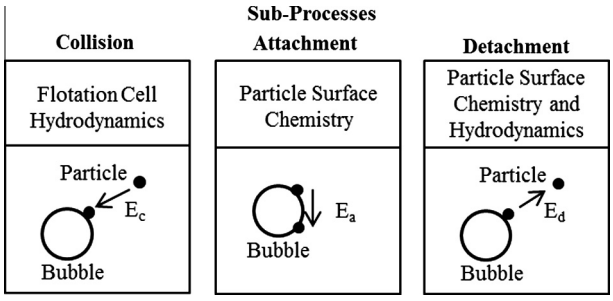

Fig. 1. Collision, attachment and detachment processes controlling the collection efficiency in mineral flotation.