Powder Technology 297 (2016) 202–210

Contents lists available at ScienceDirect

Powder Technology

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

Effect of pulp chemistry and solids on a froth bubble size measurement method

C. Bhondayi [a,*], M.H. Moys [b], G. Danha [a]

[a] Department of Civil and Chemical Engineering, University of South Africa, Private Bag X6, Johannesburg, South Africa
[b] School of Chemical and Metallurgical Engineering, University of the Witwatersrand, Private Bag 3, Johannesburg WITS 2050, South Africa

ARTICLE INFO

Article history:
Received 5 January 2016
Received in revised form 30 March 2016
Accepted 20 April 2016
Available online 21 April 2016

Keywords:
Froth bubble size
Froth phase
Conductivity
Intra-bubble impact distance

ABSTRACT

The effect of pulp chemistry and the presence of solids on a froth bubble size measurement method developed by Bhondayi and Moys (2014) was tested. Three conditions representing different pulp chemistries and two solids loading conditions were investigated. Bubble size measurements were performed in both a laboratory mini-flotation column and a mechanical cell. Results established that estimates for bubble sizes from the new method termed intra-bubble impact distances (IID) can be measured irrespective of the pulp chemistry and also that the presence of solids does not affect the method. The IIDs were on average higher than the Sauter-mean diameter which agrees with results reported by Bhondayi and Moys (2014). Although the presence of solids precluded comparison with the photographic method in the mechanical cell, at low solids content (mini-flotation column) a linear correlation existed between average IIDs and Sauter-mean diameter obtained from photographs. The presence of significant amount of solids (mechanical cell tests) changed coalescence dynamics as shown by a deviation from a linear correlation observed with low %solids and two-phase systems.

1. Introduction

The development of a new technique to estimate froth bubble sizes in flotation machines was reported by Bhondayi and Moys [2]. Testing of this electro-resistive technique was carried out in a two phase system (air and water) with the froth being generated from water containing Cu^{2+} ions. Results reported proved that froth bubble sizes can be estimated from the intra-bubble impact distances (IID) obtained using the new technique. IIDs were defined as the distance between points of significant impact while points of significant impact were defined as those points in the output signal where there are sharp drops in voltage i.e. where the probe has made contact with a liquid film. All the results reported by Bhondayi and Moys op cit were done in a solution containing significant amounts of dissolved copper ions which increased the electrical conductivity of the liquid films. This high ion content may have enabled the bubble-sizer circuit to follow the minute changes in voltage as the probe cuts across the froth. However, the bubble-sizer is intended to work in an environment that may not contain Cu^{2+} ions but other dissolved metallic ions. To establish whether the new technique works on froths of any chemical compositions and still gives reliable results i.e. an output signal suitable for bubble size estimation, the bubble-sizer needs to be tested in pulps/water with different chemical compositions. We envisage that the minimum ion content that can guarantee observable changes in electrical conductivity in froth bubble size measurements will occur in froths formed by distilled water but obviously minimum frother content will be required to stabilise the froth. If results obtained are comparable to the photographic method, then we can conclude that the new technique would work in any industrial froth since industrial froths have significant amounts of dissolved ions.

This work focuses on testing the suitability of the froth bubble-sizer as developed by Bhondayi and Moys [2] in estimating bubble sizes in froths generated from water dosed with different amounts and species of dissolved ions. Bubble size measurement on froths generated from (1) rand water (tap water), (2) Sodium hydroxide (NaOH) and limestone were performed and evaluated against results obtained using copper sulphate as reported by Bhondayi and Moys. Further experiments to test whether the presence of solids on bubble lamellas would affect the electrical signal were also done using slurry containing 2% *w/w* $CaCO_3$ and slurry obtained from an operating industrial flotation plant operating at 35% *w/w* solids content. Solids content with limestone experiments were kept low to avoid interference with froth photographs while tests with increased %solids were done to imitate industrial conditions.

2. Bubble size measurements in flotation

Over the years several techniques to estimate bubble sizes have been developed. These techniques can be broadly categorised into

* Corresponding author.
E-mail address: cbhondayi@gmail.com (C. Bhondayi).

http://dx.doi.org/10.1016/j.powtec.2016.04.027
0032-5910/

photographic methods, electrical conductivity, electrooptical and light scattering methods [3]. In the flotation field, Chen et al. [4] identified five techniques including photographic and image analysis techniques, methods based on drift flux calculation, methods based on equivalent volume cylinder formed when bubbles are drawn into a capillary (UCT method) and fibre optics to measure bubble velocity and intercepted chord. Although successfully applied in laboratory environments, only the UCT method and the photographic techniques have been tested at an industrial scale. In spite of the industrial applications, the methods are suitable for pulp-phase bubble size measurement. The photographic method has been applied in measuring foam bubble sizes in laboratory environments [1,5] but has not been applied in industry because it requires the flotation cell walls to be transparent. Methods based on conductivity, have shown potential for use in estimating froth bubbles with researchers such as Pacho and Davies [7], Xie et al. [8] suggesting ways to do so. Bhondayi and Moys [2] also suggested a conductivity based method to estimate froth bubble sizes. The technique involves dropping a thin conducting probe through the froth, the probe has a very sharp point (0.3 mm) that conducts electricity and has a sharp response whenever it impacts a bubble surface. This data can be analysed to yield Intra-bubble Impact Distances (IIDs) which are related to the size of the bubble. Details of the principle of operation and a description of the measurement procedure are given in Bhondayi and Moys op cit.

3. Experimental methods

3.1. Mini-flotation column tests description

Experiments were carried out in a mini-flotation column (13 cm × 14 cm × 50 cm) by dropping the conductivity probe into the froth from a fixed height above the surface of the froth using an experimental set-up shown in Fig. 1. Pulps with different chemical constituents were used to generate froth. Chemicals such as sodium hydroxide and calcium carbonate were added to water in the mini-flotation column to form a 0.0075 M solution and 2% *w/w* solids respectively. A base condition where ordinary tap water with frother was used to generate froth was also investigated. Air flowrate to the flotation column was maintained at 8.5 l/min resulting in a froth height of 11.7 cm and a superficial velocity (Jg) of 0.8 cm/s. Dowfroth 250 supplied by Betachem (Pty) Ltd and oleic acid (88%) supplied by Merck chemicals in South Africa were used as frother and collector respectively. Dowfroth was added at a rate of 20 mg/l of water while oleic acid dosage was 0.3 mg/100 of limestone. Slurry conditioning times were set at 2 min for oleic acid and 1 minute Dowfroth. The conductivity probe was dropped several times into the flotation column from a height of 24 cm above the surface of the froth. Concurrently, still pictures of the froth were also taken using a Samsung ES90 digital camera. The output voltage response was recorded on a PC through a data logger SCX1-1520 supplied by National Instruments. A sampling rate of 40 kilosamples/s (kS/s) was set for all measurements. Analysis of the data was done with particular emphasis on signal sensitivity and suitability for bubble size estimation. A Matlab script was generated to analyse the signal from the bubble-sizer, the code enabled calculation of the output signal derivative, identification of the points of significant impact in the signal and calculation of IIDs.

3.2. Experimental set-up for froth bubble size measurement in mechanical flotation cell

Measurement of bubble sizes in three-phase froths was done in a mechanically agitated 20 litre variable depth flotation cell. The flotation

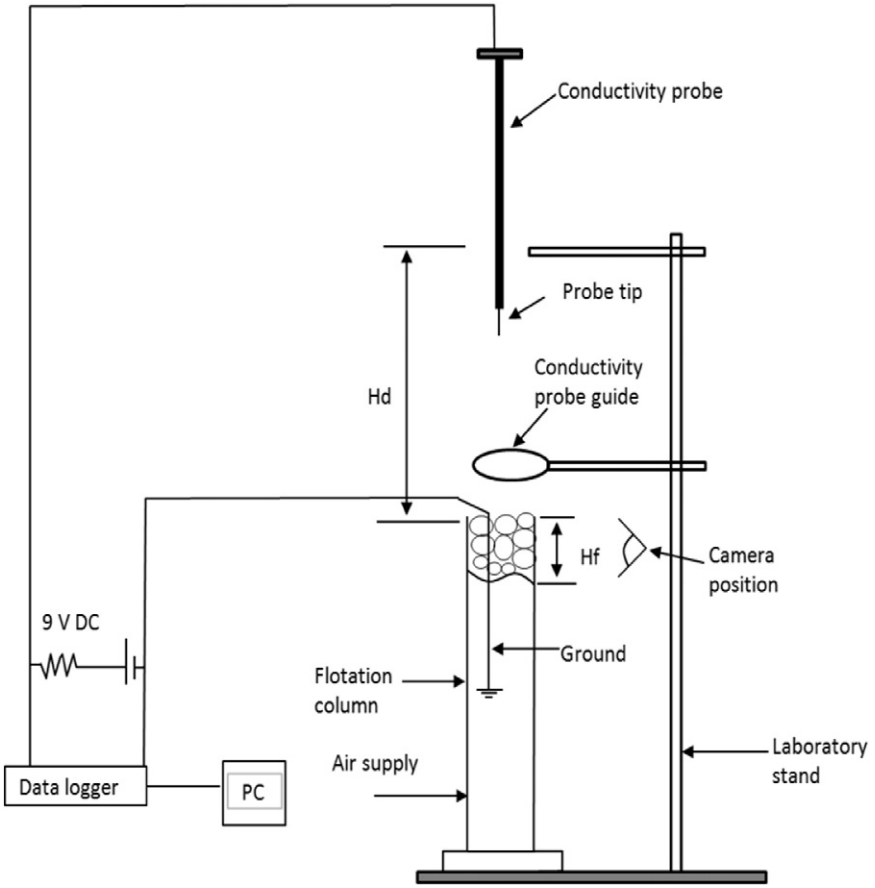

Fig. 1. Schematic of the experimental set-up to measure bubble size in the mini-flotation column, modified from Bhondayi and Moys [2].