A Preliminary study of three-phase column flotation process monitoring using electrical capacitance volume tomography

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Abstract. A preliminary study of three-phase column flotation process using electrical capacitance volume tomography (ECVT) has been conducted. The purpose of this study is to investigate the possibility of ECVT method as a monitoring system by correlating the relative permittivity distribution (or three-dimensional image) with metallurgical performance (recovery of the process). Experiments were performed in a laboratory-scale flotation column with ECVT sensor embedded outside the pipe wall on the collection zone. The feed used was a synthetic ore consisting of sphalerite and silica with the purity of 99%. Process parameter used was air flow rate ranging from 2-4 l/m which each process was conducted for 10 minutes. The results showed that the ECVT method could observe the dynamic process of flotation, specifically in monitoring a feeding process and a separation process. They were indicated by increased and decreased relative permittivity distributions respectively. Relative permittivity signal and metallurgical performance have a good correlation and showed a positive correlation. These results show a prospect of ECVT method as the monitoring system in the flotation process, but further works need to be done for this monitoring system.

1. Introduction

Flotation is a mineral separation process based on the difference in mineral’s surface properties whether it is easily wetted (hydrophilic) or difficult to be wetted by water (hydrophobic). By adding some reagents, a valuable mineral normally has hydrophobic property, while a gangue mineral has hydrophilic property. Therefore, the valuable mineral will be attached and lifted by bubbles as a concentrate product, whilst the gangue mineral will be kept in the column as a tailing product. The success indicator in this separation process is known as metallurgical or flotation performance. It reflects on the value of recovery and grade of the valuable mineral. To date, in the existing flotation industry, metallurgical performance is estimated by analyzing froth surface from 2-dimensional sequence images captured by a camera or video camera [1-3]. This technology assumes that froth characteristics are related to the process in the collection zone where bubble-particle interaction takes place. It is very important to investigate directly since it can reveal dispersion characteristics which affect the metallurgical performance.
Electrical capacitance volume tomography or ECVT is a capacitance-based tomography technology which utilizes the nonlinear distribution of electric fields to reconstruct a three-dimensional image of different materials in the imaging region [4]. ECVT technology has been used widely in two- and three-phase processes on some industrial applications [5-10]. ECVT technology has some advantages such as non-invasive and non-intrusive as well as high-speed capability measurements. Due to its advantages, the dynamic process inside the column is not disturbed since the ECVT sensor are embedded outside the pipe wall.

In this study, a preliminary study of column flotation process in a three-phase system is monitored using ECVT. This study desires to know the 3-D ECVT image results during the flotation process and to correlate the recovery of process and relative permittivity signal (extracted from 3-D images). This preliminary study will assess the possibility of ECVT technology to be implemented on the flotation process monitoring. A laboratory-scale flotation column and 8-ch ECVT sensor as the main equipment are used to conduct this study.

2. Research Method
Experiments were performed using the laboratory-scale flotation column with dimensions of 5 cm and 125 cm in diameter and height respectively. 50 cm from the sparger, ECVT sensor is installed on the outside of the pipe wall of flotation column connected to a data acquisition system and a personal computer for monitoring purpose. ECVT sensor consists of 8-electrode (square-shape, 2-plane) with a side length of 3.5 cm which each plane is shifted one another for better reconstruction image. The data acquisition system is working on 18.4 Vpp and frequency of 2.5 MHz. Both ECVT sensor and data acquisition system were manufactured at C-Tech Labs Edwar Technology. Feed used was synthetic ore consisting of silica 40 g and sphalerite 60 g which purity of both minerals was 99%. All variables were set constant, except for air flow rate. Constant variables were particle size -100+140#, solid percentage 10%, potassium amyl xanthate 0.05 g (collector), CuSO₄ 0.05 g (activator), Na₂SO₄ 0.05 g (pH regulator), and Dowfroth 1012 30 ppm (frother). Air flow rate used was 2-4 l/m with an interval of 0.5 l/m. Experimental set-up can be seen in Figure 1.

![Figure 1. Experimental set-up for three-phase column flotation process monitored by ECVT](image)

The flotation process was performed for 10 minutes for each parameter. Before the flotation process was started, the feed was conditioned for 5 minutes and the ECVT system was calibrated for imaging
purpose as well as the column was filled by air bubbles generated by the air compressor. Then, feed was poured into the column with the air flow rate of 1 l/m. Concentrate and tailing products then were analyzed by X-ray fluorescence for elemental analysis of each product and calculating the recovery of process in a given parameter. On the other hand, 3-D ECVT image results were reconstructed using linear back projection in the off-line mode which voxels (volume elements) were the basic data for further analysis. Principle of ECVT method can be read in [4].

3. Results and Discussion

3.1 Flotation Process Monitored by ECVT Method

Figure 2 shows typical 3-D ECVT image of flotation process which the colors from blue to red indicate low and high relative permittivities respectively. Since the flotation process is a complex process involving multi-phase (gas, liquid, solid), thus the colors on 3-D ECVT image are affected by their phases. Air has the lowest relative permittivity than other materials. Therefore, the blue color indicates the region with air-dominant phase, while the red color is otherwise. As shown in Figure 3, the air-dominant phase lies in the center of the column. Figure 3 shows the flotation process progression monitored by ECVT method. As shown in Figure 3, the relative permittivity signal (extracted from 3-D ECVT image) increases during the feeding process then it decreases at a certain point during the separation process. The increase of signal is due to the increase of solid-phase poured into the column, while the decrease of signal is due to the separation process which is separated as the concentrate and tailing products. Solid-phase such as zinc sulfide has a high relative permittivity that can increase the capacitance signal. Moreover, the flotation process progression is clearer by seeing the change of color from images over time. 3-D ECVT image not only reveals the global condition, but also it can investigate the local condition by analyzing voxels in the volume of interest. It is one of the benefits resulted by ECVT technology in which existing monitoring technology in the flotation process cannot investigate it.

![Figure 2. 3-D ECVT image of column flotation process with air flow rate of 3 l/m](image-url)
3.2 Correlation of metallurgical performance with relative permittivity

Figure 4 shows a correlation graph between metallurgical performance (recovery) and relative permittivity. As shown in Figure 4, the graph has a positive correlation. The highest recovery is around 40% where the air flow rate used is 2.5 l/m. By visual observation (image is not shown), the flow pattern is homogeneous when the air flow rate is lower or equal than 2.5 l/m, while the flow pattern becomes inhomogeneous at the air flow rate higher or equal than 3 l/m. The homogeneous flow pattern is preferred in the flotation process due to better stability to capture particles by bubbles resulting in higher recovery. While the inhomogeneous flow pattern will intensify the detachment mechanism of particle caused by different bubble size within the column. Different bubble size means the different velocity of individual bubble which can trigger bubble coalescence resulting bubble detachment. Therefore, the valuable mineral is constantly inside the column and recovered as the tailing product.
4. Conclusion
A preliminary study of three-phase column flotation process monitoring has been performed using ECVT. A laboratory-scale flotation column and 8-ch ECVT sensor are the main equipment for this investigation. The results show that the dynamic nature of process typically occurred in flotation can be monitored by ECVT method which is indicated by the change of relative permittivity distribution during the process. Relative permittivity signal extracted from 3-D ECVT image rises in the feeding process and decline at a certain point in the separation process or the steady state condition. The blue color at 3-D ECVT image indicates the region with a higher gas-phase concentration in which it is concentrated at the center of the column. Furthermore, metallurgical performance (recovery) and relative permittivity signal are well correlated which have a positive correlation. This preliminary study shows the possibility of ECVT method as a monitoring system in terms of control system and process optimization in the column flotation process. Although, further works need to be done to realize this method in the flotation industry.

5. References
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