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The Effect of Ultrasound Pre-Treatment on Froth Flotation Performance

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***Abstract*—**The aim of this study is to compare the effect of the ultrasonic pre treatment on the removal of heavy metals (Iron, Zinc and Copper) from Acid Mine Drainage (AMD) by Denver Cell flotation. Synthetic AMD and individual metal solutions are used in the initial experiments to optimise the process conditions for real AMD. Three different process methods, ultrasound treatment followed by Denver flotation cell, Denver flotation cell alone and ultrasonic treatments run simultaneously with the Denver flotation cell were tested for every sample. Precipitation of the metal solutions by using sodium hydroxide (NaOH) and application of the optimum frother dosage followed by flotation significantly reduced the metal content of the AMD.

***Keywords*—**Ultrasound; Denver cell; Flotation; Heavy metals; AMD

I. Introduction

ULTRASOUND technology has been widely used in the removal of impurities from minerals. Qi (2002) examined the effect of ultrasound on zinc removal from hydroxide precipitates, as well as the separation of zinc hydroxide and gypsum precipitates by dissolve air flotation. Using carboxy-methyl cellulose (CMC) as a depressor for calcium oxide minerals in flotation, result shows that ultrasound treatment improves the mechanical removal of the zinc hydroxide from the surface of the gypsum particles. Kyllonen *et. al*. [4], have demonstrated mineral processing techniques for the remediation of soil by heavy metals, aided by ultrasound treatment. Ozkan *et. al*. [1] used an ultrasonically assisted flotation cell to remove ash from coal. The application of ultrasonics to the flotation cell yields more combustible recovery and lower ash value in the concentrates than conventional flotation. Abrego (2006) removed heavy or toxic metals from residual, industrial and municipal waters and sludge by using an ultrasound flotation technique and eucalyptus as a sequestering agent. The treated water from his work complied with ecological standards.

Research to date has tended to focus on extraction of minerals rather than removal of metals from wastewater. The aim of this paper is to examine the effectiveness of ultrasonic pre-treatment in the removal of heavy metals from Acid Mine Drainage (AMD) combined with froth flotation. The Denver cell is the main flotation unit used in industry, combined with a suitable frother and optimum pH adjustment. This paper has been divided into three parts. The first part deals with individual metal solutions, second part deals with the mixture of the metals (synthetic AMD) and final part deals with the real AMD.

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II. Materials and Methods

The metal solutions used in this experiment were prepared from pure metal compounds, Zinc sulphate hepthahydrate, $ZnSO_4.7H_2O$, Copper (II) sulphate, $CuSO_4.5H_2O$) and Iron (III) sulphate penthahydrate $Fe_2(SO_4)_3.5H_2O$ supplied by Fisher Chemicals. 50 ppm concentrate of individual solution for every metal was prepared with distilled water. Two litre of every sample put into a container and was adjusted to pH 9 by using sodium hydroxide solutions. A Denver cell was used as the flotation unit. Three different experiments were conducted, one with the pre-treatment of ultrasound prior to flotation, second without the pre-treatment and the third with ultrasonic and flotation operating simultaneously. Frother type A845 0.15ml/l was use for every sample and 3 minutes conditioning time was applied to the pulp. Sample for analysis were taken every 2 minutes until flotation time has expired. The samples were than analysed by Atomic Absorption Spectrophotometer (AAS) and the removal results between the three methods were compared. Experiments then followed with mixed solutions of the three metals (synthetic, sAMD) and real AMD taken from Wheal Jane Mine water, Cornwall.

III. Experimental Methodology

This study was designed to determine the effect of ultrasonic pre treatment on metal removal from AMD solutions. In order to know the capabilities of the ultrasound pre-treatment, three different methods were used in this experiment. Flotation with Denver Cell alone, second sample was pre treated with ultrasound for ten minutes; follow by flotation with Denver Cell and finally the AMD was treated with flotation and ultrasound which operated simultaneously. The Denver Cell was operated at optimal conditions after various parameters for pH, impeller speed, froth type and dosage concentration being tested.

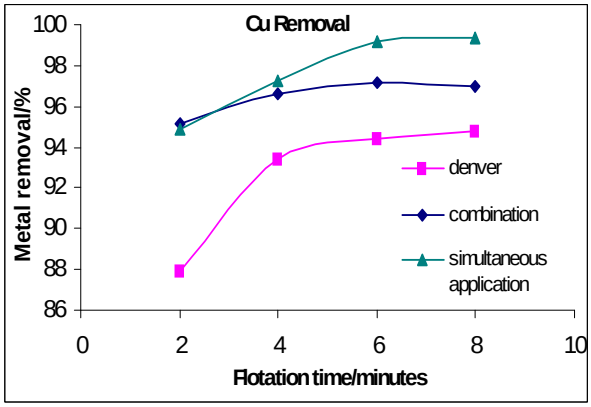
TABLE I
DENVER CELL AND SAMPLE OPTIMUM CONDITIONS

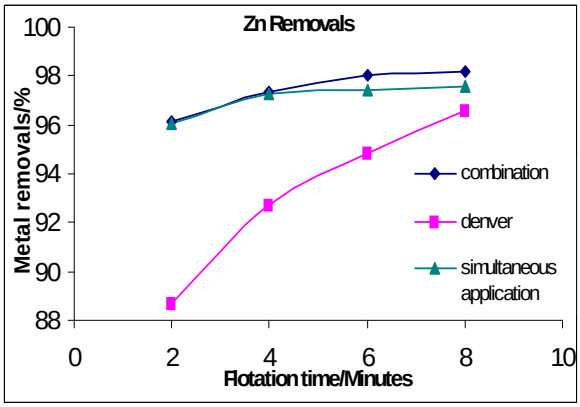
Floatation Machine	Denver cell
Impeller speed	1000rpm
Sample	50 ppm of 2 litre synthetic metals
Frother	0.15ml/l of A845
Temperature	Ambient
pH	9 with NaOH
Flotation time	8 minutes
Ultrasound time	10 minutes
Conditioning time	3 minutes

IV. RESULTS AND DISCUSSION

The results for every experiment are given in Figures 1 – 3. Figure 1 shows the graph for every different technique used for individual metal solution removal of copper, zinc and iron respectively.

Previous studies discussed in the introduction were designed to determine the effect of ultrasound in flotation to extract valuable minerals from their impurities. The present study however, is aimed to remove the impurities i.e. precipitated metal hydroxide from wastewater before it can be discharged to the environment. The results of this study show that ultrasound pre-treatment achieves a significant improvement in metal removal in the first 2 minutes of flotation compared to flotation without the ultrasound pre treatment. At the end of the flotation time (8 minutes), it can be seen in Figure 1 that metal removal with ultrasound pre-treatment gives a higher removal than flotation alone.





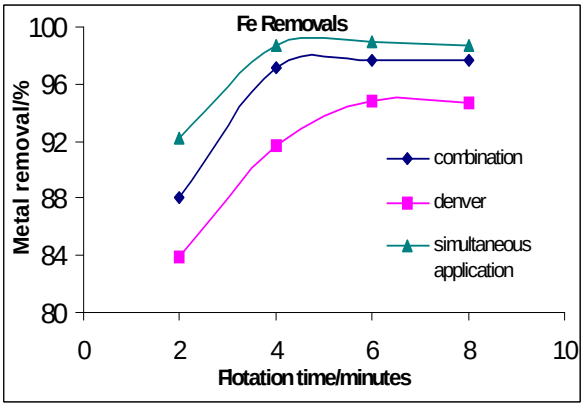
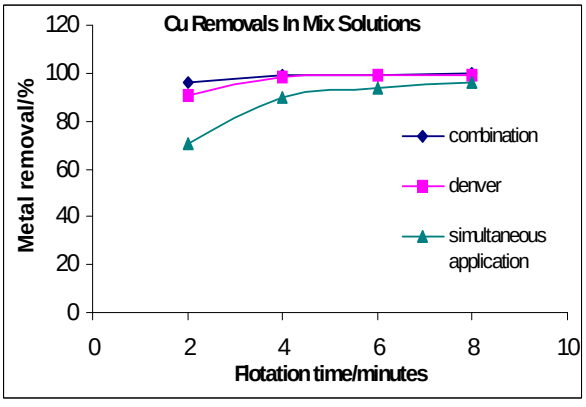
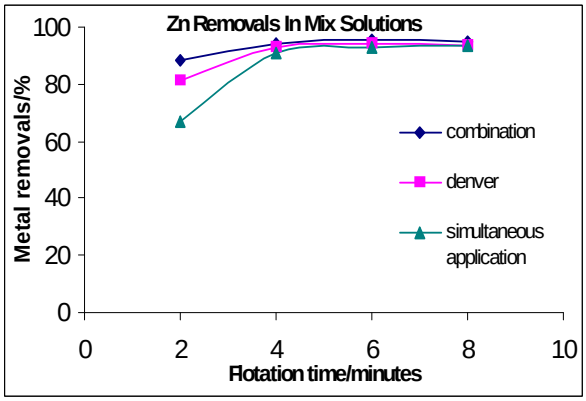


Fig. 1. Comparison of metal removal against time in their solution between the three methods

Further experiments using combined samples of the three metals to mimic the Acid Mine Drainage were carried using same experimental method. Analysis with AAS shows that the pre-treatment with ultrasound followed with Denver cell flotation still give higher metal removal as expected. Figure 2 shows the metals removal performance in the mixture solutions with the three different methods.





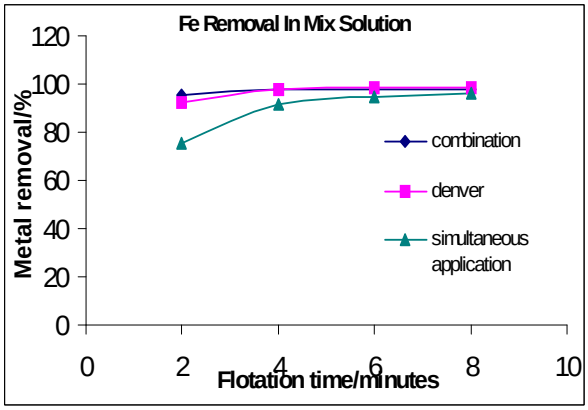
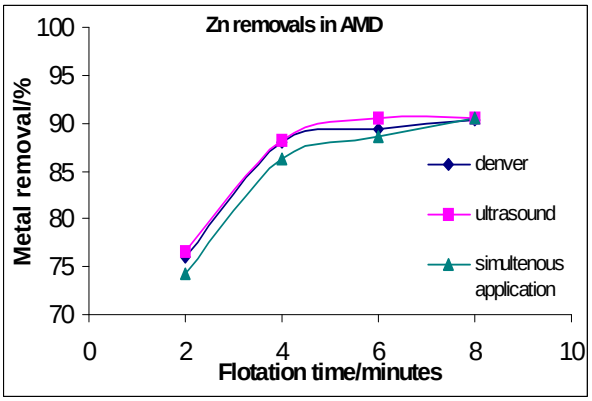


Fig. 2. Comparison of metal removal against time in mixed solution between the three methods



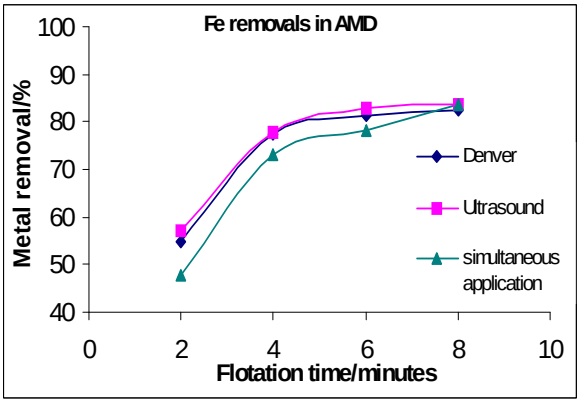


Fig. 3. Comparison of metal removal against time in rAMD sample between the three methods

The same trend was achieved with the sAMD sample for the first 2 minutes of flotation. In Figure 2, the removal from four to eight minutes flotation time looks similar for every metal and clearly suggests that the majority of metals were all removed before the four minutes of the flotation.

The final stage of this experiment, which was very important to this study is the treatment applied to the real AMD. However, there is no copper detected from the sample collected from the Wheal Jane site. Initial treatment with the same set of parameters applied to the previous experiments did not give an impressive result. To overcome this, it was deemed necessary to increase the frother dosage until a stable froth was stable using the real AMD and clear water drainage. 0.3ml/l of frother A845 was found the optimum dosage for rAMD.

As it can be seen in the Figure 3, both Zn and Fe have a maximum removal in occurrences of ultrasound pre treatment. These indicate that the application of ultrasound during flotation has a capability to increase the metal precipitate removal from AMD at the correct dosage of frother and flotation time.

The chemical effects of ultrasound do not come from a direct interaction with molecular species. Instead, sonochemistry and sonoluminescence arises from acoustic cavitations: the formation, growth, and implosive collapse of bubbles in a liquid. Acoustic cavitation provides a unique interaction of energy and matter, and ultrasonic irradiation of liquids can cause high-energy chemical reactions to occur [7]. The results of this study indicate that pre-treatment of the metal solutions with ultrasound can cause small particles of metal hydroxide to collide into one another and enhance subsequent froth flotation. They are bound together after the impact and form bigger metal hydroxide particles. This bigger particle will later float more easily in the Denver cell.

V. Conclusions

Ultrasound pre-treatment enhances the metal removal when coupled with the flotation system. The early stage of the treatment (first 2 minutes of flotation time) is very important part of ultrasonic effect. Up to 3% of removal difference compared to the Denver cell alone was achieved by using ultrasonic treatment. The correct pH for the metal to precipitate and optimum dosage of suitable frother however are other major contributors to the success of this technique.

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