THE DEVELOPMENT OF AN IMPROVED METHOD FOR COMPARING DEPRESSANT BEHAVIOR IN FLOTATION USING MACHINE VISION

G. S. Heinrich, L. Burdukova, D. J. Bradshaw and P. J. Harris
Mineral Processing Research Unit, University of Cape Town, Cape Town, South Africa.
E-mail: liza@chemeng.uct.ac.za

ABSTRACT

In flotation, depressants are used to reduce the amount of gangue that reports to the concentrate and hence increase the selectivity of the flotation process. At the University of Cape Town extensive batch flotation tests are carried out to evaluate industrial depressants and standard procedures have been developed over the years.

This study was conducted in order to develop an improved method for comparing depressants using machine vision as an aid. The modified method of batch flotation involved a test with prolonged intervals between scraping to allow more time for the froth to build up and mature.

This method of testing showed increased differences between the flotation performance obtained as represented by grade recovery curves for carboxymethyl cellulose and guar depressants when compared to the standard method of testing with shorter scraping intervals. The improvement was attributed to reduced entrainment resulting from longer drainage time in the froth and therefore yielded a better test for comparing depressants on the basis of true gangue flotation with minimized entrainment. As expected, the sulphide recoveries were unaffected by the change in method. The machine vision system also added to the information obtained during these tests by recording bubble size trends throughout the tests which were later analyzed and related to the amount of flotable gangue in the froth. Modifications are recommended to improve the usefulness of machine vision in batch flotation.

Keywords: Batch flotation, Machine Vision, Depressants

INTRODUCTION

Flotation is a separation process dependent on differences in hydrophobicity between valuable material and unwanted gangue. Reagents are added to manipulate the surface properties of the minerals to enhance their separation.

Depressants are utilized in flotation to reduce the hydrophobicity of gangue and so to reduce the amount of gangue particles that report to the concentrate and therefore increase grade of the concentrate by improving selectivity. Entrainment is the process whereby particles are unselectively carried into the froth phase by fluid resulting from the upward motion of the bubbles. Depressants do not directly control the amount of gangue that enters the froth unselectively through entrainment; however, indirectly entrainment is affected by froth stability [Savassi, 1999; Robertson, 2002]. Evaluation of depressant behaviour is frequently based on laboratory-scale batch flotation tests. Such tests often form the basis for industrial choices of reagents and conditions and, therefore, extracting as much meaningful information as possible from them is essential.

It was established that the appearance of the froth surface is intimately linked to the metallurgical performance of the flotation cell [Sweet, 2000; Moolman et al., 1998; Lenczowsky, and Galas, 1998].

Hence, the control of flotation plants rests on the operators’ visual inspection of the froth surface and their opinion thereof. It has been proposed that machine vision technologies could be used to extract useful data from the froth surface and can be integrated into online control or measuring schemes [van Schalkwyk, 2003].
A Machine Vision software system Smartfroth [Wright, 1999; Sweet, 2000; Hatfield 2003] has been developed by the Mineral Processing Research Unit at the University of Cape Town for various research applications. It has been used in bench-scale batch tests as well as plant testing for the platinum and copper industry. It uses a watershed algorithm to segment bubbles to obtain froth surface descriptors such as froth velocity, bubble size distribution and most recently bubble stability [Wright, 1999; Sweet, 2000; Hatfield, 2002]. The main objective of this research was to improve the method used for comparing depressants in batch flotation tests while using machine vision technology.

**EXPERIMENTAL**

**Materials**

A platinum bearing ore from the Merensky reef near Rustenburg, South Africa has been used throughout. The ore contains approximately 1% sulphides (chalcopyrite, pentlandite and pyrite) and 5% talc with the remaining gangue consisting mainly of pyroxene and feldspar. The behaviour of the sulphides relative to the total gangue is used as a measure of metallurgical performance in this work.

**Depressants**

The two depressants used were Dep-267, a carboxymethyl cellulose (CMC) supplied by Akzo Nobel Functional Chemicals and APX-4M, a guar gum supplied by APX Guar Pty (Ltd). One of the major differences between these two polysaccharides is that CMC is anionic whereas guar typically has little or no charge. Due to the electrical charge, CMC macromolecules can have dispersing characteristics in addition to depressant action.

**Procedure**

Each test used a 1-kg sample of Merensky ore. The ore was ground down to a particle size distribution of 60% below 75 μm. The dosage of collectors added to the mill was 40 g/ton of Senkol 5 as well as 40 g/ton of SIBX. All the flotation tests were performed in a 3 litre modified Leeds batch flotation cell using 40 μl of DowFroth 250 frother. Following conditioning with frother for 1 minute, 50 g/t of the specified depressant was added and conditioned for 1 minute. The airflow rate was set at 5 l/min, while the stirring rate was kept at 1200 rpm. The froth height was maintained at 2 cm.

The standard method of batch flotation involved a 20 minute test with the froth being scraped every 15 seconds. Four concentrates were collected at 2, 6, 12 and 20 minutes respectively. For the modified method of batch flotation the froth was allowed to develop for 2 minutes and was scraped at 1 minute intervals thereafter. Four concentrates were collected at 2, 6, 12 and 20 minutes respectively. The sulphur assays were performed using a Leco Sulphur Analyzer.

<table>
<thead>
<tr>
<th></th>
<th>Modified Method</th>
<th>Standard Method</th>
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<tbody>
<tr>
<td></td>
<td>Guar CMC</td>
<td>Guar CMC</td>
</tr>
<tr>
<td>Final sulphur grade (%)</td>
<td>5.57 0.41</td>
<td>4.30 0.15</td>
</tr>
<tr>
<td>Final sulphur recovery (%)</td>
<td>75.37 1.51</td>
<td>73.84 6.67</td>
</tr>
<tr>
<td>Mass yield of froth product (g)</td>
<td>30.59 2.83</td>
<td>39.72 0.93</td>
</tr>
<tr>
<td>Entrained mass (g)</td>
<td>5.73 0.56</td>
<td>9.93 1.90</td>
</tr>
<tr>
<td>Floating gangue (g)</td>
<td>20.13 2.17</td>
<td>25.41 0.04</td>
</tr>
<tr>
<td>Water (g)</td>
<td>204.0 20.0</td>
<td>353.0 67.7</td>
</tr>
<tr>
<td>Sulphide mass (g)</td>
<td>4.73 0.09</td>
<td>4.45 0.07</td>
</tr>
</tbody>
</table>

Table 1. Summary table of results.
RESULTS AND DISCUSSION

All the tests were carried out in duplicate and a summary of the average results are shown in Table 1.

![Graph showing sulphur grade vs. recovery curves for guar and CMC](image1)

**Figure 1.** Sulphur grade vs. recovery curves obtained for the two depressants guar (APX4M) and CMC (Dep 267) using different concentrate removal methods.

**Metallurgical Results**

Figure 1 shows that the use of the standard testing method resulted in similar sulphur grade-recovery curves for the two depressants. The modified method with prolonged intervals between scrapes however gave results that showed significant differences between the two depressants. The modified method also yielded higher values for overall grade while overall recovery was found to be statistically similar for the two methods for both depressants.

Higher average overall recoveries were obtained using the CMC for both methods of testing, although this difference was statistically insignificant due to variation in the individual tests. The higher grades obtained with the guar demonstrated that it was a stronger depressant at the low dosages used.

The reason for the differences in depressant performance between the two methods of testing can be attributed largely to the difference in the degree of entrainment as explained below:

![Graph showing mass pull vs. water for guar and CMC](image2)

**Figure 2.** Average mass pull vs. water obtained for the two depressants guar (APX4M) and CMC (Dep 267) using different concentrate removal methods.
Figure 2 shows similar mass to water relationships for all conditions, however the modified method of testing reduced the total amount of water and total amount of mass recovered for both depressants. This in turn reduced the amount of entrained gangue as entrainment has been shown to be closely related to water recovered [Savassi, 2000]. Work by Robertson (2002) revealed that for this system of batch flotation of Merensky ore, in a 3 litre modified Leeds flotation cell with a 2 cm froth height, entrainment was related to water by the following equation: \( \text{Entrainment}(g) = 0.0281 \times \text{water}(g) \) and that this relationship did not vary significantly with changes in reagents and test conditions. The mass entrained was assumed to be entrained gangue as the contribution of entrained sulphides would be very small. The mass of floating gangue was calculated by subtracting the entrained mass and floating sulphide mass from the total mass recovered. From this the curves shown in Figure 3 were obtained.

![Figure 3. Entrained mass vs. time obtained for the two depressants guar (APX4M) and CMC (Dep 267) using different concentrate removal methods.](image)

Figure 3 shows a significant decrease in entrainment for both depressants using the modified method. This can be attributed to the lower amount of water that was recovered using this method. For both methods less mass was entrained using the guar than the CMC.

![Figure 4. Floating gangue vs. time obtained for the two depressants guar (APX4M) and CMC (Dep 267) using different concentrate removal methods.](image)
Figure 4 shows that the modified method of concentrate removal also decreased the amount of floating gangue for both depressants. This demonstrated that both the contributions of entrainment and floatable gangue were reduced by allowing the froth to mature. However the quantity of sulphides that reported to the concentrate was not reduced as shown in Figure 5.

As Figure 5 demonstrates neither the method of testing nor the depressant choice had a detrimental effect on the recovery of the valuable sulphide minerals reflected by the sulphide mass recovery results.

These results imply that as sulphides were not affected by the modified method but floatable gangue was reduced, froth crowding seemed to be taking place with preferential placement of the more hydrophobic sulphide minerals. This resulted from the longer sampling time of the modified method, allowing more time for the froth to drain and therefore allowing entrained as well as partly hydrophobic gangue particles to leave the froth [Warren, 1984]. This supports the argument that froth drainage and resulting froth recovery is selective [Seamen, 2002]. The modified batch flotation test amplified differences in depressant performance as the contribution of entrainment was significantly reduced and the true flotation of gangue was highlighted.
Machine Vision Results

Figure 6 represents a typical machine vision response for an experiment performed using the standard method of testing. The vertical lines represent the scraping intervals. The broken line represents actual test data, while the solid line represents a moving average of this data.

It can be seen that the bubble size rises to a maximum and then falls to a local minimum after scraping. It then rebuilds up to a smaller peak and falls to a minimum again after the following scrape until after about 100 seconds when the bubbles do not build up significantly after scraping. The bubble size for the guar appears to increase with time after 200 seconds but this was due to incorrect segmentation of the bubbles by Smartfroth due to the presence of small bubbles at the end of the guar tests. The Smartfroth software should be modified to properly address this issue.

![Figure 6. Machine Vision results for the standard method of testing using 50 g/t of Dep-267 depressant and AXP-4M depressants.](image)

As can be seen in Figure 7, the results for the modified method of testing differ from those for the standard method of testing.

A more stable froth was observed and the bubble size shows a period of large bubbles similar to those obtained using the standard method until about 60 seconds when the bubble size drops and does not build up significantly again.

This difference between the methods of testing was due to the increased sampling interval period where the froth was allowed to mature. As can be seen from the metallurgical results, the amount of floating gangue was reduced by the modified method reflected by the higher grades. This corresponded to the faster reduction in bubble size observed in the modified tests and indicated that bubble size could be related to the amount of talcaceous gangue present in the froth. This should be evaluated more rigorously.

CONCLUSIONS

The following conclusions can be drawn from this study:

The differences between CMC and guar were amplified using the modified method of testing compared to the standard method of testing. This was due to the longer time allowed for the froth to mature compared to the standard method. The reduced entrainment when more time was allowed for froth drainage therefore yielded a better test for comparing depressants on the basis of true flotation with minimised entrainment. The implications of these findings could greatly benefit the research and scale up of reagent testing to full scale operation.
Higher overall sulphur grades were obtained using the modified method of testing. This was due to the longer time allowed for froth drainage and therefore resulted in a froth with less entrained gangue. The modified method of testing reduced the amount of flotable gangue reporting to the froth without affecting sulphide recovery. This was attributed to froth crowding and the preferential attachment of the more hydrophobic sulphide minerals.

Guars were shown to be more effective than CMCs as depressants at low dosages resulting in less flotable gangue and higher sulphide grades, although slightly higher recoveries when using CMCs could be due to slime cleaning effects.

The machine vision analysis showed that no large bubbles formed after the first sample was collected when using the modified method while large bubbles continued to form after the collection of numerous samples when using the standard method of testing and this corresponded to the higher grade and lower flotable gangue obtained with the modified method of testing. This can be attributed to the reduction of talcaceous gangue reporting to the froth in the modified method. Limitations with the machine vision software with regard to the minimum bubble size needed for accurate segmentation were identified and further development is needed.

REFERENCES

Creese G. and Malan T., 1999. The use of froth visualisation techniques to compare the effects of chemical and physical parameters on floatation performance, Undergraduate thesis, University of Cape Town, Rondebosch


