THE EFFECT OF DRY AND WET GRINDING ON GOLD ORE FLOTATION

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ABSTRACT

In this study, the effect of dry and wet grinding on the flotation of gold ore was investigated comparatively with and without (collectorless) a collector (potassium amyl xanthate, PAX). In flotation tests with PAX, a rougher concentrate containing 11.04 ppm Au was obtained with 85.47% recovery following wet grinding while obtaining a rougher concentrate having 42.54 ppm Au with 85.10% recovery after dry grinding. The concentrate obtained following dry grinding had four times higher Au grade. In collectorless flotation tests, a rougher concentrate containing 7.68 ppm Au were obtained with 57.70% recovery following wet grinding while obtaining a rougher concentrate having 29.07 ppm Au with 67.85% recovery after dry grinding. Dry grinding resulted in both higher grade and recovery compared to the wet grinding in collectorless flotation. Overall, Au grades and recoveries of obtained concentrates were higher in both wet and dry grinding conditions with collector compared to the collectorless flotation. Further collectorless flotation tests with dry ground samples were carried out in order to increase Au grades and recoveries. Finally, a rougher concentrate containing 44.88 ppm Au was acquired with recovery of 82,63%.

Keywords: Gold ore, gold flotation, wet/dry grinding, collectorless flotation

INTRODUCTION

Gold is a relatively rare metal and the average content in the earth's crust is about 3ppb (O'Connor and Dunne, 1994). Recovery of native gold from gold ores varies according to the nature of the deposit, ore mineralogy and gold distribution of the ore (Allan and Woodcock, 2001). Generally concentration methods include gravity, often gravity in combination with flotation and/or cyanidation. Among these methods flotation come into prominence due to the cost effectiveness (Bulatovic, 1997; Bulatovic and Wyslouzil, 2000). Flotation of gold and gold-bearing minerals can be classed into five categories (Dunne, 2016),

- Flotation of native or free gold,
- Flotation of telluride minerals,
- Flotation of gold-carrying iron sulfides,
- Flotation of aurostibite, stibnite, and maldonite,
- Flotation of copper-gold ores.

Native or free gold is assumed to be naturally hydrophobic (Dunne, 2016). Especially, untarnished gold with appropriate particle size could easily be floated with only a frother (Aksoy and Yarar, 1989). Flotation of native gold including gold associated with easily flotable minerals is achieved at a natural ore pH by using no collector (collectorless) and generally, small dosages (<10 g/t) of uncharged water insoluble collectors (Klimpel, 1999).

Grinding conditions have an important effect on the concentration response of the minerals in successive processing methods, particularly in flotation. Wet grinding is often preferred prior to flotation due to the fact that flotation is performed wet. Dry grinding is usually preferred in regions where water is scarce and following process is dry. The effect of wet and dry grinding environment prior to flotation of sulfide ores has been a subject of limited studies (Farrokhpay and Manouchehri, 2012; Feng and Aldrich, 2000; Koleini et al., 2012; Palm et al., 2010; Seke, 2005). In the case of sphalerite ore, dry grinding resulted in more positive pulp potentials, oxidizing environment, compare to the wet grinding. Furthermore, the grades and recoveries of sphalerite were higher as opposed to wet grinding (Koleini et al., 2012; Liu et al., 2018; Palm et al., 2010; Seke, 2005).

In this study, the effect of dry and wet grinding on the flotation of gold ore was investigated comparatively with and without (collectorless) a collector.

MATERIAL AND METHOD

A bulk sample of a gold ore was used in this study. It was initially crushed below 8 mm by using a jaw crusher then further crushed below 3 mm using a roll crusher. This sample was then split into 500 g bags to be used as a feed to a rod mill and kept frozen in the fridge when not being handled. A cylindrical laboratory rod mill with a diameter of 200 mm and a length of 250 mm was used in grinding tests with 60% solids. Grinding media was stainless steel rods with a weight of 12900 g. The crushed ore samples were ground at pre-determined time in wet and dry conditions to obtain P_{80} size of 75µm. The particle size distributions of the dry and wet ground samples were determined using Malvern Mastersizer Hydro 2000-MU instrument and illustrated in Figure 1. As seen particle size distributions in the case of dry and wet grinding conditions are quite identical.

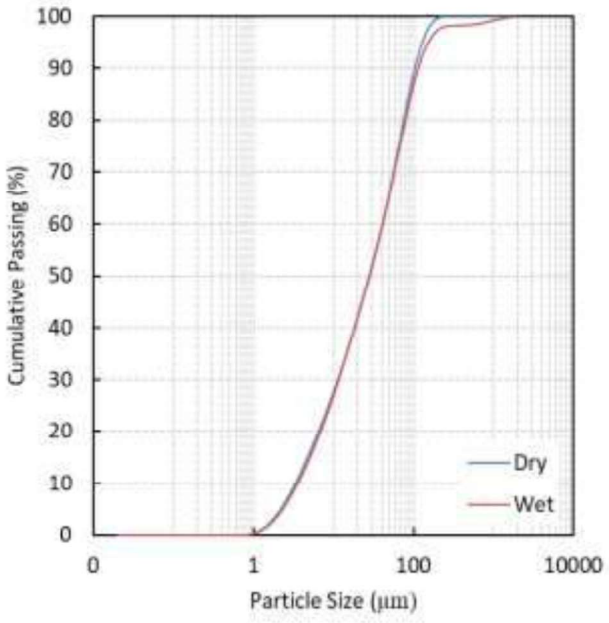


Figure 1. Particle size distribution of the dry and wet ground samples

Rougher batch flotation tests were performed in a 1.5 L Denver flotation cell. Tap water was used to make up approximately 35% solids by weight. The impeller speed was set at 900 rpm and the air flow rate was maintained at 5 L/min. 30 g/t Aerofroth 70 (AF70, Solvay Chemicals Inc.) was used as a frother and 30 g/t potassium amyl xanthate (PAX) as a collector. The pH was natural ore pH of 7.9. The pulp was agitated for a period of 6 min., so that any differences in pH between each test would be

stabilized. In the case of flotation tests with collector, extra 3 min. of conditioning time was allowed. Frother was added and conditioned for 1 min. before the air entered the pulp. Scraping of the froth was performed every 15 s. Three rougher concentrates were taken after 30, 60 and 180 s. These concentrates were dried and weighed and prepared to be shipped for analysis. Flotation performance was evaluated based upon Au grades and recoveries.

All the feed samples and flotation test products were analyzed at Bureau Veritas Commodities Canada Ltd., Vancouver, BC, Canada by ICP-ES/ICP-MS and by fire assay for gold. The average feed assays for gold and the other major elements are given in Table 1 The mineralogy is dominated by quartz and mica with moderate amounts of feldspar, carbonates and minor amounts of clay, magnesium silicates and sulfides (chalcopyrite and pyrite) Gold mainly is in the form of free gold or native form.

Table 1. Assays of feed sample

Au (g/t)	Ag (g/t)	Cu (g/t)	Fe (%)	S (%)
3.91	1.36	45.00	1.35	0.23

RESULTS AND DISCUSSIONS

The effect of dry and wet grinding on gold flotation with collector is given in Figure 2. It can be seen that Au recoveries are quite similar in both grinding conditions while Au grades being significantly higher for the dry ground sample especially at shorter flotation times. This indicates that dry grinding resulted in much better selectivity compare to the wet grinding condition. Increased selectivity in dry ground samples could be attributed to the less hydroxides formation on gold surfaces compare to the wet grinding (Chapman et al., 2011; Palm et al., 2010).

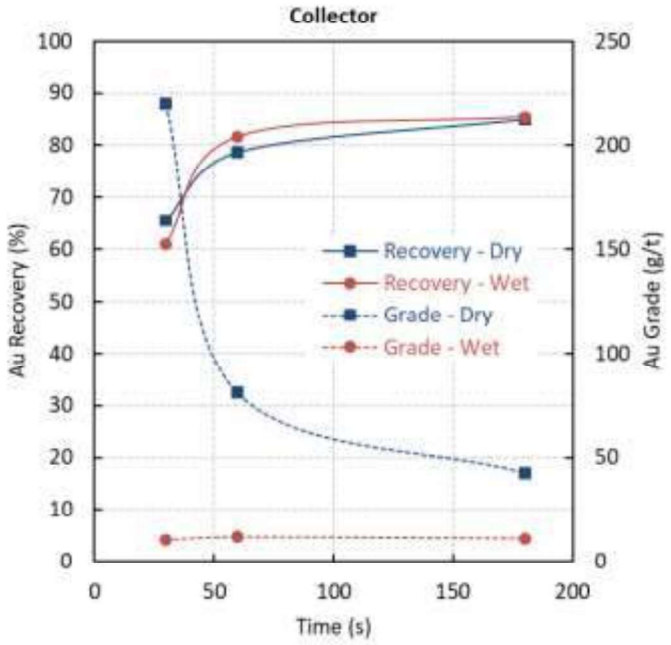


Figure 2. The effect of dry and wet grinding on gold flotation with collector

In collectorless flotation, the dry ground samples exhibited much higher Au recoveries and grades then the wet ground samples as shown in Figure 3. Dry grinding led to better selectivity in

collectorless flotation as well. The negative effect of wet grinding on gold flotation might be due to the formation of hydroxide coating on gold surfaces through galvanic interaction (Chapman et al., 2011; Palm et al., 2010).

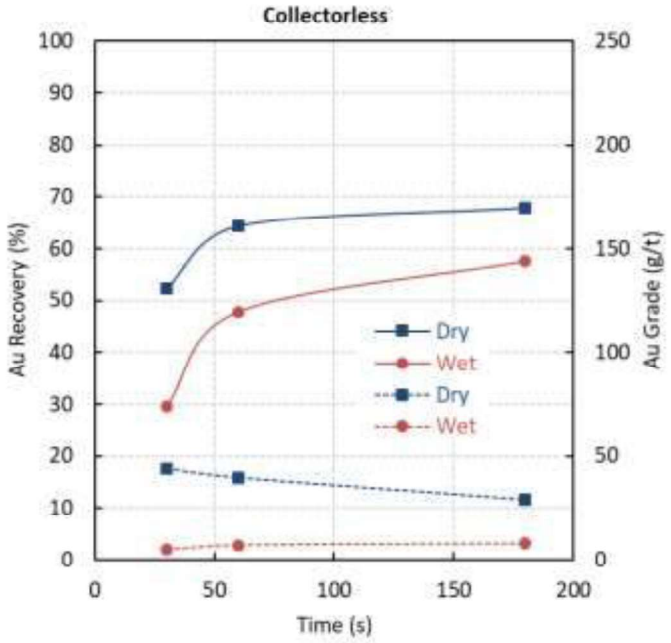


Figure 3. The effect of dry and wet grinding on gold flotation without a collector

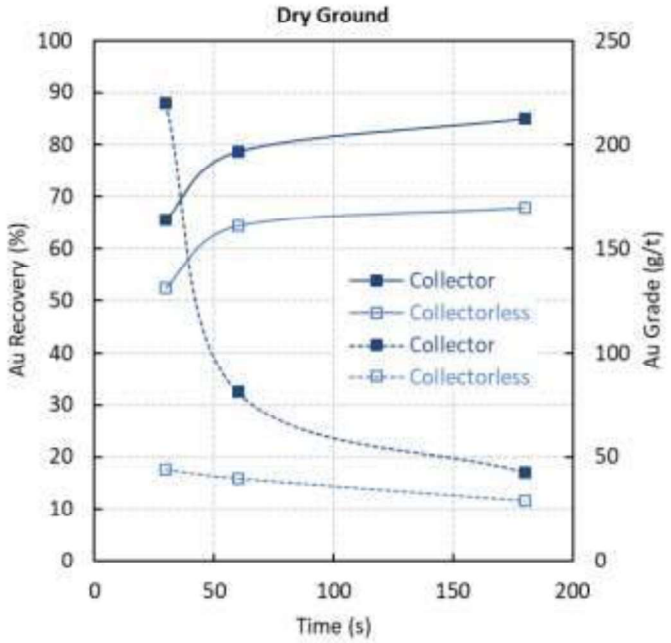


Figure 4. Comparison of the gold flotation after dry grinding

The comparison of gold flotation with and without collector after dry grinding is presented in Figure 4. Au recoveries and grades increase significantly with collector addition. Gold flotation results with and without a collector after wet grinding given in Figure 5. Collector addition resulted in better gold flotation following wet grinding conditions as well.

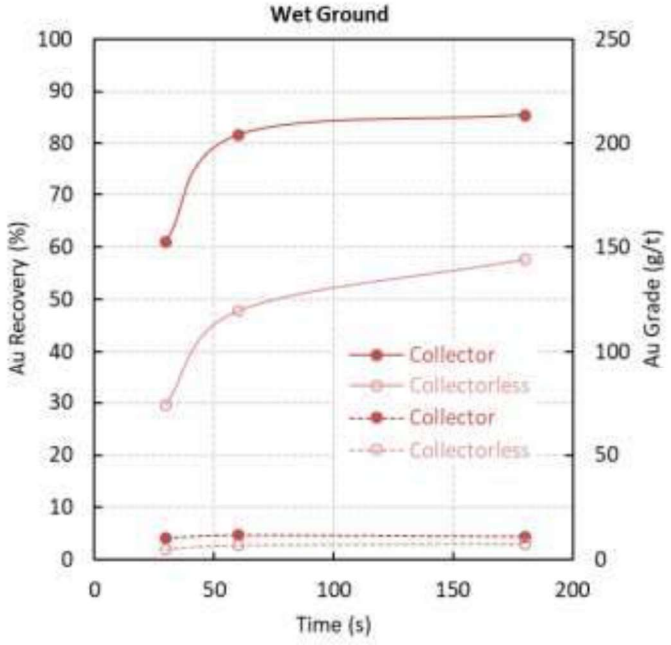


Figure 5. Comparison of the gold flotation after wet grinding

Dry grinding prior to gold flotation seems to have some potential in terms of gold selectivity especially in collectorless flotation (Figure 3 and 4). Therefore, supplementary collectorless flotation tests were performed on dry ground samples. The effect of longer conditioning (LC) on collectorless flotation was examined. In this test, 30 min of extra conditioning time was allowed before the froth collection. The results are presented in Figure 6.

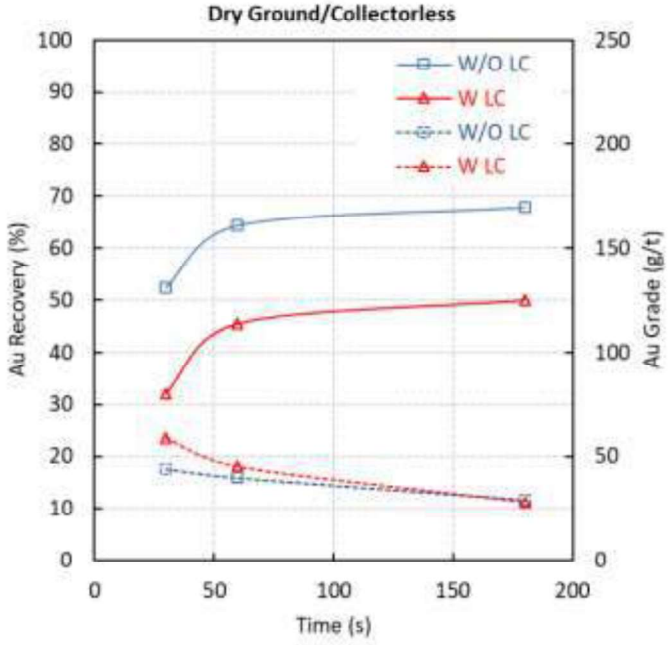


Figure 6. Effect of long conditioning (LC) on collectorless flotation

As seen in Figure 6, longer conditioning (LC) resulted in lower Au recoveries. This could also be interpreted as possible coating of hydroxyl species on gold surfaces with a prolonged time of conditioning as observed after wet grinding. The behavior observed in Figure 6 suggests that the effect of short conditioning (SC) needs to be tested as well. In this test, no conditioning was allowed before the froth collection (i.e. rougher concentrate collected immediately). The results are presented in Figure 7. It is interesting to note that Au recoveries and grades increase significantly similar to that of with collector. This indicated that gold could well be floated successfully in collectorless flotation conditions. Collectorless flotation of gold after dry grinding has not been investigated by others according to the authors' literature knowledge.

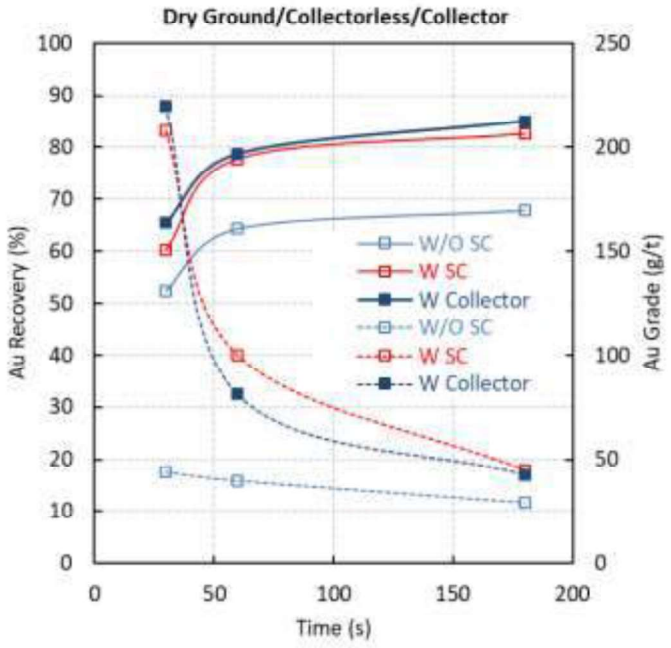


Figure 7. Effect of short conditioning (SC) on collectorless flotation

CONCLUSIONS

In this study, the effect of wet and dry grinding on the flotation of a gold ore was investigated with and without a collector (collectorless). In flotation tests with collector, a rougher concentrate containing 11.04 ppm Au was obtained with 85.47% recovery after wet grinding while obtaining a rougher concentrate having 42.54 ppm Au with 85.10% recovery after dry grinding. The concentrate obtained following dry grinding had four times higher Au grade with similar recoveries. In collectorless flotation tests, a rougher concentrate containing 7.68 ppm Au were obtained with 57.70% recovery following wet grinding while obtaining a rougher concentrate having 29.07 ppm Au with 67.85% recovery after dry grinding. Dry grinding resulted in both higher grade and recovery compared to the wet grinding in collectorless flotation. Overall, Au grades and recoveries of obtained concentrates were higher after both wet and dry grinding conditions with collector compared to the collectorless flotation. Nevertheless, it was found that dry grinding preceding to gold flotation has some potential in collectorless flotation. Furthermore, the effect of conditioning time on collectorless flotation was examined and a rougher concentrate containing 44.88 ppm Au was acquired with the recovery of 82,63% at short conditioning time. As result of this study, it is worth to mention that collectorless flotation was proved to be an effective means in gold ore flotation.

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