Short Communication

A new collector scheme for strengthening ilmenite floatability in acidic pulp

Jihua Zhai a,d, Xiaolong Lu a, Pan Chen a,b,c,*, Changping Guan a, Wei Sun a,b, Wei Chen c,*

a School of Minerals Processing and Bioengineering, Central South University, Changsha 410083, China
b Key Laboratory of Hunan Province for Clean and Efficient Utilization of Strategic Calcium-Containing Mineral Resources, Central South University, Changsha 410083, China
c Hunan Research Institute for Nonferrous Metals, Changsha 410100, China
d School of Civil Engineering, University of Leeds, Leeds LS2 9JT, UK

Article history:
Received 20 March 2019
Accepted 12 July 2019
Available online 27 July 2019

Keywords:
Ilmenite
Decanoic acid
Oleate
Acidic floatability

ABSTRACT

For a long time, ilmenite floatability in strongly acidic pulp has not received enough attention, which violates compliance requirements for the industrial production of ilmenite concentrate. In this present study, decanoic acid was found to be an effective collector, to float ilmenite in strongly acidic pulp (especially for the pH range from 3 to 6). The combination of decanoic acid and oleate proved to be significant in improving ilmenite floatability within a broad pH range, and especially at a pH around 4. The most synergistic and effective result occurred when the ratio of decanoic acid and oleate was 1:2, and the difference in flotation recovery of ilmenite and titanaugite was also increased at a pH around 4. Therefore, the collector scheme with a 1:2 ratio of decanoic acid and oleate was significant in strengthening ilmenite flotation behavior and its selective separation.

© 2019 Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

1. Introduction

Titanium resources are quite abundant in China, and according to USGS data, China’s total reserves of titanium resources account for approximately 29% of the world’s gross reserves. However, the main form of existing titanium resources in China is refractory ilmenite-containing minerals, in comparison with the more highly exploited rutile-containing minerals [1,2]. Panzhihua, located in the southwest area of the Sichuan province, is the main provenance of ilmenite-containing ores, and its total reserves accounts for approximately 90% of the total reserves in China [3,4]. Historically, flotation has served as the primary method for upgrading ilmenite, and the collector plays an important role in this process. Past research has been devoted to studying the flotation behavior of ilmenite and its associated gangues via various surface modification methods [5–8]. However, a vital issue that has been regularly ignored is the improvement of ilmenite floatability in acidic pulp. Although some efforts have shown that collectors, such as succiniminate, mixed oleic acid and lauryl trimethyl ammonium bromide, and phosphoric acid esters, can be used for
ilmenite flotation in acidic pH range [1,9], the most reported and widely used collector is sodium oleate. Fig. 1 summarizes previous results concerning ilmenite floatability at pH values of 6 and 4.

It can be seen easily that ilmenite flotation deteriorates significantly at a strongly acidic pH when using oleate as the collector. For the industrial production of ilmenite concentrate in the Panzhihua area, cleaning operations are generally conducted in strongly acidic pulp, and the three-cleaning method was industrially adopted to produce qualified ilmenite concentrate. The relevant pH values are generally maintained between 3.9 and 2.8 for the three cleaning operations [12]. Therefore, methods to improve ilmenite floatability in strongly acidic pulp are of great significance and exhibit compatibility with common industrial practices. However, little has been reported on this subject until now. In this study, a collector scheme was found to be effective in improving ilmenite floatability in acidic pulp, and the scheme is discussed herein.

2. Materials and methods

Analytical sodium oleate and decanoic acid were obtained from Baisaiquin Chemical Technology Co., Ltd., Shanghai, China. Sodium hydroxide and sulphuric acid stock solutions were used to adjust the pH, and deionized water (Resistivity = 18.3 M x cm) was used throughout the experiments. Pure ilmenite and titanagite samples were obtained from Panzhihua, Sichuan province, China, after a series of purification procedures were conducted using repeated magnetic and gravity separation. Subsequently, the products were sieved and the samples with a fractional size of ~0.074 + 0.038 mm were used for micro-flotation experiments. The XRD patterns of pure ilmenite and titanagite samples are shown in the supplementary material provided with this report.

An XFG-1600 type (mechanical agitation) flotation machine with a volume of 40 mL was used for the micro-flotation tests. For the single mineral flotation tests, the impeller speed was fixed at 1700 rpm, and the mineral suspension was prepared by adding 2.0 g of pure samples to 30 mL of solution. The pH of the mineral suspension was adjusted to the desired operating value by adding H₂SO₄ or NaOH stock solutions. The collector was added and conditioned for 3 min, and flotation concentrates were then collected for a total of 3 min. The floated and un floated particles were collected, filtered, and dried, and the recovery was calculated based on solid weight distributions between the two products [6,13].

3. Results and discussions

Fig. 2 presents the ilmenite flotation results as a function of pH and decanoic acid concentration. It can be seen that the optimal pH range for ilmenite flotation was from 3 to 6, and that collector concentration promoted ilmenite recovery remarkably. When the pH and collector concentrations were 4 and 3 × 10⁻⁴ mol/L, respectively, ilmenite recovery reached as high as 90%. Regarding oleate, its optimum pH range for ilmenite recovery was from 6 to 8, and its optimal value is generally considered to be 6 [4,7,13]. Therefore, decanoic acid was an effective collector to float ilmenite at strongly acidic pH values of around 4. However, the drawback was that ilmenite recov-
very decreased as pH increased, and when pH was around 6, the recovery was much lower. Therefore, the combined use of olate and decanoic acid was expected to have the potential ability to float ilmenite effectively within a broader pH range. The proportion of decanoic acid to olate was first taken into consideration, and the flotation results are shown in Fig. 3.

Fig. 3 shows that the proportion of decanoic acid to olate had some influence on ilmenite recovery, and as the ratio of olate increased, the ability of the combined collector to float ilmenite was first strengthened, and then weakened. The recovery was much higher when the ratio of decanoic acid to olate was 1:2 and 1:3, compared to the cases when decanoic acid or olate was used individually. Meanwhile the most synergetic effect occurred when the ratio of decanoic acid to olate was 1:2, and in this case ilmenite recovery was 87.54%, exhibiting a significant increase compared to solo olate (82.46%) and solo decanoic acid (49.65%).

The influence of pH on ilmenite recovery using the combined collector at a fixed ratio of 1:2 was studied, and for a better comparison, flotation behavior of titanaugite (the primary gangue in existence) was also studied. The results are shown in Fig. 4(a), and Fig. 4(b) depicts the relevant results using solo olate as the collector.

By comparing the results shown in Fig. 4, it can be seen that the combined collector had an improved and effective ability to float ilmenite within a much broader pH range. Compared to solo olate as the collector, the recovery of titanaugite using combined collector seemed a little higher but not obvious. Flotation recovery difference between ilmenite and titanaugite at pH around 4 was enlarged from approximately 9.7% (olate) to 47.87% (combined collector). The combined collector strengthened ilmenite floatability and improved the selective separation of ilmenite from titanaugite. Therefore, it can be concluded that the combined collector scheme, a 1:2 ratio of decanoic acid to olate, was much more effective and significant in ilmenite flotation studies because of its factual compliance with the industrial practice for ilmenite concentrate production.

4. Conclusions

In this study, decanoic acid was found to be an effective collector for floating ilmenite. Further, the optimal pH range for ilmenite floatability was within a strongly acidic region and at approximately 4. A new collector scheme, consisting of a 1:2 ratio of decanoic acid to olate, was introduced and evaluated in an ilmenite flotation system, and the results showed that the combined collector was much more effective for floating ilmenite compared to those results using widely accepted olate (in previous studies) as the collector. The optimal pH range for ilmenite flotation was enlarged to more acidic region by the combined collector, which was quite beneficial for enhancing flotation separation, and coincided more closely with the cleaning operations used in the industrial production of ilmenite concentrate.

Conflicts of interest

The authors declare no conflicts of interest.

Acknowledgements

The authors acknowledge the support of the Hunan Provincial Natural Science Foundation for the youth, China (2018JJ3665), China Postdoctoral Science Foundation (2019M650188), the Natural Science Foundation of China (51504290), the National Science and Technology Support Program of China (2015BAB19B01), and the Key Laboratory of Hunan Province for Clean and Efficient Utilization of Strategic Calcium-containing Mineral Resources (No. 2018TP1002).

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.jmrt.2019.07.019.
REFERENCES


