Flowsheet development for low-grade manganese ores by physical and physicochemical methods

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ABSTRACT

In this research, to achieve an appropriate flowsheet for processing of low-grade manganese ore, some kinds of beneficiation methods have been investigated and compared. The used ore sample contains an average grade of 13.8% MnO. The valuable mineral containing manganese is pyrolusite, and calcite is the main gangue mineral in the ore. Gravity (jigging and tabling), high-intensity magnetic and flotation (cationic and anionic) methods were examined this study. Among the applied methods, cationic flotation has the highest manganese recovery in the concentrate (77.4%) with a selectivity index of 2.34. The highest grade of MnO in the concentrate is 52.6% with a selectivity index of 4.10, which is obtained using high intensity wet magnetic separation. The highest separation efficiency (almost 54.2%) is also achieved by this method. For developing a suitable flowsheet, the combination of various methods including gravity-flotation (cationic and anionic), gravity-magnetic, and gravity-gravity were examined. Among the combined methods, the combination of tabling and cationic flotation methods has resulted in a concentrate containing 39.9% MnO with an acceptable recovery of 71.5%, which seems more suitable flowsheet for development in the industrial scale.

KEYWORDS

Manganese, Pyrolusite, Beneficiation, Flowsheet, Gravity separation, Magnetic separation, Flotation.

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1. Introduction

Manganese with special physico-chemical properties is mainly used in the various industries including metallurgy, battery making and chemical [1]. The accepted commercial manganese concentrate should be contain more than 40% Mn (51.6% MnO) [2]. Among minerals, pyrolusite containing 63.2% Mn is one of the most abundant and economical manganese minerals [3, 4, 5]. Nowadays, due to the reduction of high-grade manganese resources, low-grade reserves have been given more attention. In order to achieve the concentration required by manganese consuming industries from these resources, it is necessary to use different beneficiation methods [6]. Gravity, high-intensity magnetic separation and flotation are common methods for manganese minerals processing [7, 8]. Most of manganese resources are low-grade deposits which have a complex chemical composition, and manganese minerals are found in the fine grains form and scattered inside them [9, 10]. The physical methods cannot be effective for separation of fine pyrolusites disseminated inside gangue minerals [11]. Despite of manganese production in limited amount from high-grade manganese resources in the country, it is expected that soon the exploitation of low-grade resources and their beneficiation will be inevitable. One of these low-grade deposits which has been noticed recently is Amir Charagah deposit with an average grade of 13.8% MnO. In this work, the various methods including gravity, magnetic and kinds of flotation methods as well as their combination are investigated for beneficiation of Amir Charagah ore samples.

2. Methodology

In this research, the studied ore sample was taken from Amir Charagah deposit located in East Azerbaijan province. The chemical composition of ore sample and products obtained from different separation methods was determined by X-ray fluorescence (XRF). The mineralogical composition of samples was conducted by X-ray diffraction (XRD) analysis. Scanning electron microscope (SEM, XL 30 model) equipped with a WDX (Wavelength dispersive X-ray) analyzer was employed to study the minerals texture and to determine the pyrolusite liberation degree. After crushing and rod milling the samples to desired sizes, the gravity separation experiments were carried out by jigging and tabling. The wet magnetic separation of pyrolusite was conducted on samples milled under 180 μm (d_{80}=180 μm) at different intensities using a high-intensity disk magnetic separator manufactured by Box Mag Rapid Company. The anionic and cationic flotation experiments were carried out using oleic acid and dodecyl amine (DDA) collectors, respectively. Sodium carbonate and calcium chloride were used as depressant agent in the cationic flotation while sodium silicate was consumed for this purpose in the anionic flotation experiments. After grinding and desliming, 300 g of ore sample with a -150+20 μm size fraction were subjected to the flotation experiments carried out in a 1l Denver cell with a solid percentage of 25-30 % wt. After mixing the pulp for 4 min, the depressant and collector agents were added and conditioned for 5 min for each of them. Finally, after adding pine oil with a conditioning time of 2 min, the froth collection was performed for 4 min, after which the froth phase was brightened. The flotation concentrate and tailing were filtered, dried and weighed, and chemically analyzed for determining the MnO content and calculating of recovery.

3. Results and Discussion

According to the X-Ray diffractography, the studied ore consists of pyrolusite as the main valuable mineral, and calcite and quartz as gangue minerals. The chemical analysis showed that the ore containing 13.8% MnO which implies about 17% pyrolusite is one of the low-grade deposits in the world. Based on XRD and XRF analysis, almost 79% and 3-4% of the ore is formed by calcite and quartz, respectively. Based on the studies conducted by SEM the liberation degree of pyrolusite has been determined 180 µm.

Jigging and tabling as common gravity methods were examined for beneficiation of studied sample. In order to achieve a clean tailing with minimum content of MnO, the jigging experiments were performed on various size fractions. The optimal results were obtained in -9500+4750 μm size fraction with 50% of weight recovery. The optimal concentrate with 20% MnO and 77.4% recovery is favorable for other separation techniques such as tabling, magnetic separation and flotation. The separation experiments conducted by shaking table on different size fractions showed that the optimal results are obtained in the size fraction of -425+180 μm. At these conditions a concentrate with a weight recovery of 19.4% containing 42.8% MnO (with 52.1% recovery) is achieved. These results indicate that although the MnO grade in the concentrate produced by tabling is relatively high, but the MnO recovery and its separation efficiency in the jigging concentrate is significantly higher than that's of shaking table.

After crushing the sample under 10 mm, and separating the materials finer than 2 mm by screening, the material with a size of -10+2mm was beneficiated by jigging method. The jigging concentrate was mixed with materials below 2mm, and then milled under 180 μm by rod mill. This feed material was subjected to magnetic separation at different intensities. The results show that the weight percent of magnetic product and recovery of MnO increase by increasing of magnetic intensity while the MnO content is decreased slightly. The highest amount of separation efficiency (54.16) and selectivity index (4.1) are achieved in the magnetic separation with intensity of 1.77 tesla. Under this condition, an optimal concentrate containing 52.6% MnO with 64.6% recovery is produced.

The MnO content in the concentrates obtained by both cationic and anionic flotation experiments are equal, but recovery, separation efficiency and the selectivity index in cationic flotation is higher than anionic one. This means that in the flotation of pyrolusite from gangue minerals, the cationic collectors can act more selectively than anionic types.

Since the gravity, magnetic and flotation methods alone were not able to produce a manganese concentrate with the favorable grade and recovery, the combination of different methods was examined. According to the results, two combination including tabling-cationic flotation and jigging-magnetic separation are suitable for beneficiation of studied ore. The highest recovery of MnO in the concentrate and its separation efficiency are almost 71.5% and 56.1%, respectively, which are obtained by combination of tabling-cationic flotation. This concentrate contains almost 40% MnO which can be improved by cleaner stage flotation. The concentrate with the highest content of MnO (52.6%) is achieved using the combination of jigging-magnetic separation. In this concentrate, the MnO recovery and separation efficiency are 56.6% and 54.16%, respectively.

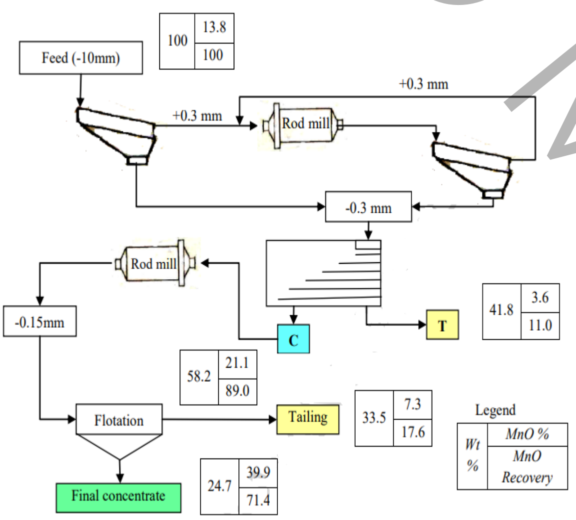

Fig. 1. Suggested flowsheet for beneficiation of Amir Charagah manganese ore based on the combination of gravity and cationic flotation.

4. Conclusion

- The concentrate with the highest MnO recovery and selectivity index is obtained in the cationic flotation using dodecylamine as collector and sodium carbonate as depressant.
- The high intensity wet magnetic separation produces a concentrate with the highest MnO content and separation efficiency.
- A manganese concentrate with the highest MnO recovery and separation efficiency is obtained by combination of tabling and cationic flotation while the concentrate with the highest MnO content is achieved using the combination of jigging and magnetic separation.
- Due to the high cost of high-intensity wet magnetic separation, and the possibility of improving the MnO content of the cationic flotation concentrate, the combination of gravity and flotation methods according to the flowsheet given in Fig. 1 is suggested for beneficiation of the studied low-grade ore.

5. References

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