24-007

Additives for Magnetic Separation of Iron Ore Ultrafines

Kelly Laranjeira Nunes
Clariant Mining Solutions, Belo Horizonte, MG

Lívia Marques Faustino
Clariant Mining Solutions, Belo Horizonte, MG

Leandro Seixas Bicalho
Clariant Mining Solutions, Belo Horizonte, MG

Wagner Cláudio da Silva
Clariant Mining Solutions, The Woodlands, TX

ABSTRACT

Seeking to implement the Global Industry Standard on Tailings Management to improve the safety of their tailings facilities across the globe, mining companies are motivated to invest in new technologies to recover valuable minerals from tailings. One solution being evaluated is the use of magnetic separators to concentrate ultrafine tailings. However, this approach is energy intensive as it requires high magnetic fields to recover ultrafines, and usually results in low mass yields. Additives that modify pulp rheology and surface properties, or selective flocculate ultrafine particles, were tested to enhance the performance of magnetic separation. Promising results in laboratory scale testing different types of additives confirmed that it is possible to increase the mass yield, keeping the selectivity of this stage.

INTRODUCTION

The Global Industry Standard on Tailings Management sets a precedent for the safe management of tailings facilities, towards the goal of zero harm to people and the environment. Therefore, mining companies are committed to implementing new technologies to recover valuable minerals from tailings, increasing production and generating less residuals (ICMM, 2020). Also, over time, the earth's resources continue to decline, leading companies to turn to tailings recovery.

Flotation and magnetic separation are the most well-known recovery methods, but when it comes to iron ore tailings, alumina content is usually high, and that brings challenges to flotation, especially of kaolinite (Rodrigues, 2012; Ma, 2009). Taking that into consideration, magnetic separation might be a great choice to concentrate iron ore tailings. However, the intensity of the magnetic, gravity, and hydrodynamic (for wet separators) forces are mainly determined by the particle size. So, the finer the particles, the less selective this process is and the higher the energy required to concentrate the minerals. (Luo, 2016; Svoboda, 2003).

Aiming to correct that, several studies are taking place worldwide, such as the incorporation of superconductivity, and improved understanding of principles of HGMS (High Gradient Magnetic Separator), among others, as shown in Figure 1. Adding to that, we present chemical additives to enhance ultrafine magnetic separation. They provide higher economic value for the concentrate, by reducing contaminants, higher productivity, and lower residue generation, increasing mass yield.

Those additives are based on three different action mechanisms: dispersion, selective agglomeration, and rheology modification. Dispersing agents attach to the mineral surface, 'cleaning' it and making it easier for the magnetic

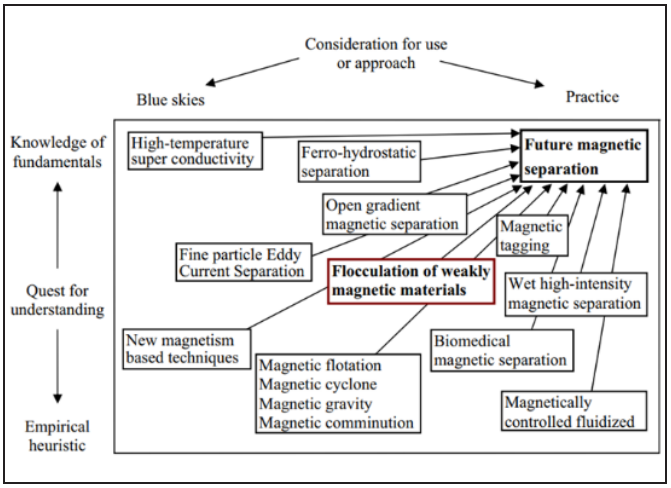

Figure 1. The future trends in magnetic separation (Luo, 2016)

Figure 2. Outotec SLon, the VPHGMS used in the tests

field to recover the minerals of interest without interference from other minerals (Morkun, 2021; Patra, 2015; Gururaj, 1983). Agglomerating agents bridge many particles of the minerals of interest together, to form larger flakes, therefore preventing the drop in recovery (Choi, 2023; Roy, 2012). Rheology modifiers change pulp viscosity to make it settle more slowly so the particles stay in suspension for enough time to be recovered (Boger, 2010; Klein, 2005).

This study aims to evaluate the performance of additives to enhance slime mass yield in high-gradient magnetic separation. For this purpose, tests on tailings were performed with and without the presence of additives. The best results are shown in this paper.

METHODOLOGY

The sample used in this study was collected from the slimes thickener of an iron ore producer in Brazil. It was characterized in terms of particle size distribution and chemical and mineralogical composition. The underflow of the slimes thickener would go through a VPHGMS (Vertical Pulsating High Gradient Magnetic Separator), shown in Figure 2, to investigate the most effective additives for magnetic separation. The non-magnetic would then compose the tailings and the magnetic, the concentrate, which would subsequently go through flotation. Table 1 describes the parameters and reagents' dosage for the tests.

Table 1. Tests parameters and reagents dosage

Parameters		Products Dosage	
pH	8	CADM	50 g/t
		23-226	100 g/t
Matrix	1.5 mm	CADM	50 g/t
		23-236	100 g/t
Magnetic field	10,000 Gauss	FLOTICOR	50 g/t
		MS 19510	100 g/t
Pulsation	20 Hz	FLOTICOR	50 g/t
		MS 19124	100 g/t
Solid content	30%–35%	CADM	50 g/t
		23-237	100 g/t
		CADM	50 g/t
		23-238	100 g/t

Table 2. X-ray fluorescence of the slimes sample

	XRF (%)
Al_2O_3	9.00
CaO	0.1
Fe	42.5
K2O	0.05
MgO	0.16
Mn	0.98
P	0.155
SiO_2	19.4
TiO_2	0.35
LOI	7.56

Table 3. X-ray diffraction of the slimes sample

	XRD (%)
Quartz	14.4
Hematite	28.6
Goethite	29.3
Kaolinite	25.8
Gibbsite	2.0

RESULTS AND DISCUSSION

Characterization of slimes

Figure 3 shows that this was a fine sample. 95% of the particles were smaller than 45 µm and 30% were under 10 µm. The main mineral components found (Table 2) were iron, silica, and alumina, common to iron ore tailings. As observed in Table 3, the iron content of this sample was spread in the forms of hematite and goethite, the latter containing impurities and being difficult to concentrate. There was also quartz, a small amount of gibbsite, and a considerably high content of kaolinite, which is a complex mineral to be floated in reverse iron ore flotation. Therefore, this sequence of processes (flotation after magnetic separation) makes it easier to achieve a cleaner concentrate, as kaolinite is not attracted to the magnetic field. However, as magnetic separators usually present low mass yields, in terms of fines concentration, the main objective was to increase mass yield at this stage.

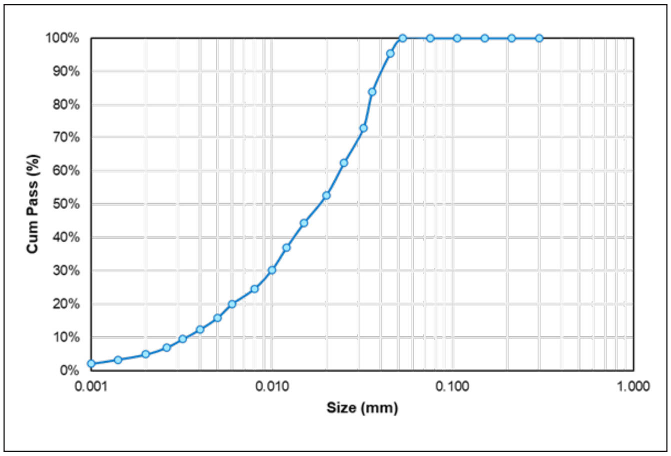

Figure 3. Particle Size Distribution of the slimes sample

Additives for Magnetic Separation

The process standard (no reagent) is a mass yield of 51% with a silica content of 9.5%. As seen in Figure 4, both dispersing agents were able to increase mass yield by up to 5%. CADM 23-226 resulted in a mass recovery of 56% and 10.4% of silica content in the concentrate, whereas CADM 23-236 resulted in a 55% mass recovery and silica content of 10.2%. Particle dispersion proved to be effective for this ore, at the dosage of 100 g/t.

In terms of agglomerating agents (Figure 5), FLOTICOR MS 19510, dosed at 100 g/t, was able to increase mass yield by 7% with a silica content of 10.5%. FLOTICOR MS 19124 also showed good performance with 57% mass recovery and 11% silica content.

The rheology modifiers presented the best result in terms of mass yield, showed in Figure 6. CADM 23-238 was able to increase mass recovery by 12%, resulting in a silica content of 11.4%, with a low dosage (50 g/t). The high silicate content is not a pressing point for this study.

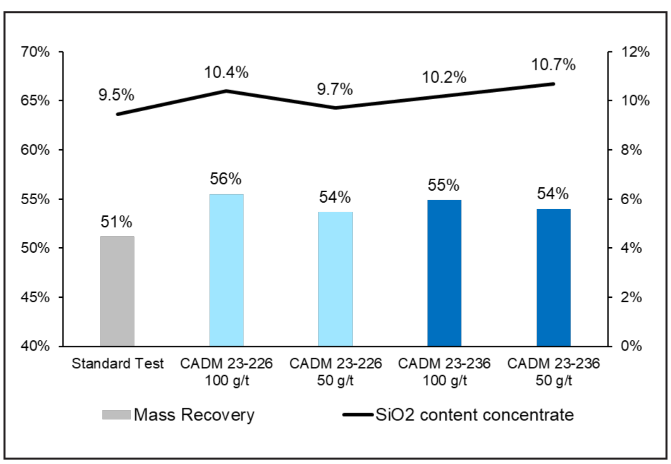

Figure 4. Tests results using dispersing agents as additives

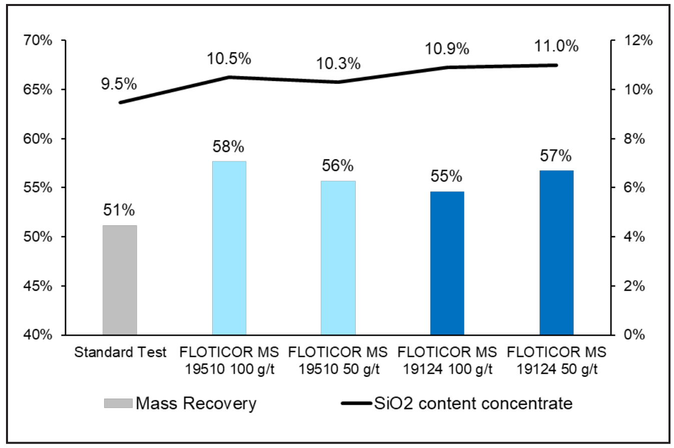

Figure 5. Tests results using agglomerating agents as additives

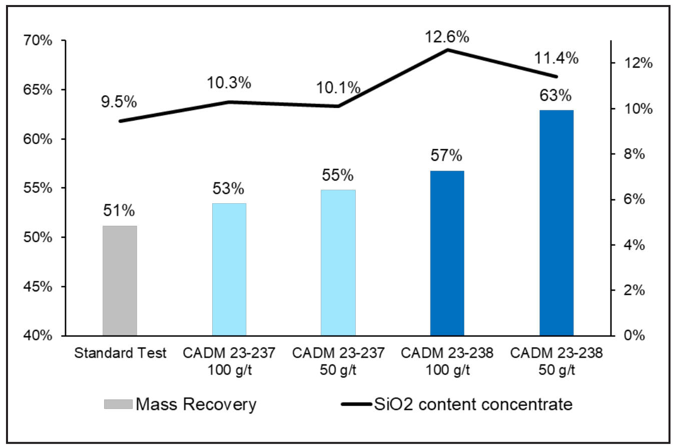

Figure 6. Tests results using rheology modifiers as additives

As mentioned before, there would be a flotation stage following magnetic separation, so concentrate quality was not the objective. However, it was observed that quality was not extremely affected by the additives as silica content remained relatively stable.

CONCLUSION

The additives were effective in enhancing slimes (with very fine material and critical mineralogy) magnetic separation in dosages of 50 g/t and 100 g/t. These initial results show that iron ore tailings can be reprocessed through high-gradient magnetic separation using the mechanisms of dispersion, selective agglomeration, and rheology modification, thus enabling the reduction of the volume of ultrafine tailings to be filtered and/or disposed of. CADM 23-238 increased the mass yield of the slimes from 51% to 63%, keeping the silica content low (11.4%), which means a 12% mass recovery increase, dosing only 50 g/t of the reagent. Further studies with magnetic separation additives should be performed with different ores in lab, pilot, and industrial scales to verify the gains in mass recovery, selectivity, concentrate quality, and energy saving.

REFERENCES

[1] Choi, Junhyun and Sang B. Kim (2023), "Influence of pH and ionic strength on the floc-magnetic separation: Selective flocculation of fine iron ore," *Results in Engineering*, September.

[2] Gururaj, B., Sharma J. P., Baldawa, A., Arora, S. C. D., Prasad, N., Biswas, A. K. (1983), "Dispersion-flocculation studies on hematite-clay systems," *International Journey of Mineral Processing*, April, 285–302.

[3] ICMM (2020), Global Industry Standard on Tailings Management.

[4] Klein, B. and M. Paulik (2005), "Rheology modifiers for mineral suspensions," in *Minerals and Metallurgical Processing*, May, 83–88.

[5] Luo, L. and Anh V. Nguyen (2017), "A review of principles and applications of magnetic flocculation to separate ultrafine magnetic particles," *Separation and Purification Technology*, July, 85–99.

[6] Ma, X., W. J. Bruckard, R. Holmes (2009), "Effect of collector, pH and ionic strength on the cationic flotation of kaolinite," *International Journey of Mineral Processing*, May, 54–58.

[7] Morkun, V., N. Morkun, V. Tron, V. Golik, A. Davidkovich (2021), "Increasing efficiency of iron ore magnetic separation by using ultrasonic technologies," in *ICSF*.

[8] Patra, A. S., D. Makhija, A. K. Mukherjee, R. Tiwari, C. R. Sahoo, B. D. Mohanty (2016), "Improved dewatering of iron ore fines by the use of surfactants," *Powder Technology*, 43–50.

[9] Rodrigues, O. M. S., A. E. C. Peres, A. H. Martins, C. A. Pereira (2013), "Kaolinite and hematite flotation separation using etheramine and ammonium quaternary salts," *Minerals Engineering*, 12–15.

[10] Roy, S. (2012), "Recovery improvement of fine magnetic particles by floc magnetic separation," *Mineral Processing and Extractive Metallurgy*, 170–179.

[11] Svoboda, J. T. Fujita (2003), "Recent developments in magnetic methods of material separation," *Minerals Engineering*, 785–792.

24-008

Alteration and Geochemistry of Clinkers in the San Juan Basin, New Mexico

Devlon R. Shaver
New Mexico Institute of Mining and Technology.
Socorro, New Mexico.

Virginia T. McLemore
New Mexico Bureau of Geology and Mineral
Resources. Socorro, New Mexico

ABSTRACT

Clinkers are the result of a seam of coal catching fire and burning the surrounding rocks. The fires caused the surrounding rocks to be baked at high temperatures, removing organic material and partially forming glass. These rocks become hard, orange, and brick like, forming clinker. The purpose of the study is to determine their potential to contain economic levels of critical minerals, including Rare Earth Elements. Some clinkers contain over 200 ppm total REE.

INTRODUCTION

The San Juan Basin consists of 24 individual coal fields present in New Mexico. Coal mining has been conducted in the state since the late 1800s, with the San Juan basin becoming heavily developed during the early and mid-20th century. Extensive mining operations took place for over a century in the Basin with numerous recent large operations taking place and countless small pits being operated. The majority of the coal resources found in the San Juan Basin are late Cretaceous in age, and are part of the Menefee and Crevasse Canyon formations of the Mesa Verde Group, and the Fruitland Formation. [1] The coal resources of the San Juan Basin are extensive, and typically occur in lensed shapes of varying thicknesses [2]. Coal seams that have, through erosion and time, become exposed to the elements can gradually break down into humates over time. Clinkers are found in areas where underground coal fires have taken place, altering the coal seam and the surrounding rock layers. Clinker deposits can be found in the Gallup, Bisti, and Standing Rock coal fields within the San Juan Basin, all areas extensively mined for coal deposits. (Figure 1). These deposits represent sedimentary beds that surrounded coal seams that burned underground for long periods of time, exposing the surrounding layers to extreme heat.

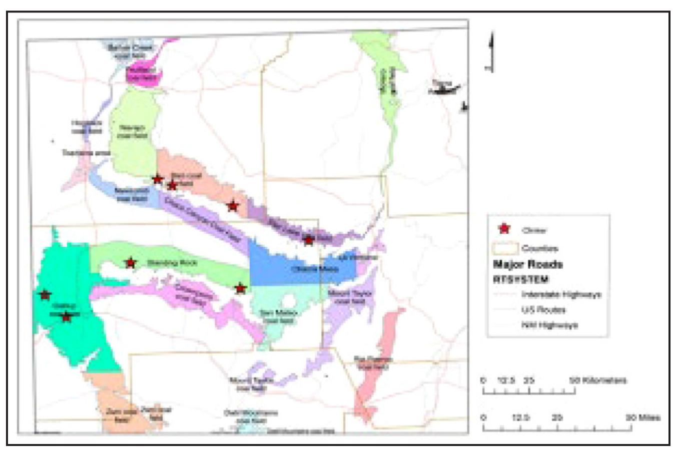

Figure 1. Map showing clinker deposits (stars) and coal fields (colored polygons) in the San Juan Basin of northwestern New Mexico