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Study of Flotation of Charcoal Fines Regarding Feed Size Distribution and Collector Concentration

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ABSTRACT

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Volume 11, Issue 2 March-April-2024 Page Number : 421-426 The cement industry Mato Grosso do Sul state in Brazil charge fines of coke and charcoal as their main fuels. Charcoal, upon arriving at the industry, is subjected to sizing steps (crushing, grinding and sieving), which is essential for a quick burning of the combustibles, generating heat to the cement production process. The coarse fraction of the charcoal sizing process is characterized by a high ash content and, consequently, a lower carbon content. To solve the problem, flotation presents itself as a process with potential for application. The aim of the work is to evaluate the feasibility of using different concentrations of collectors and particle size ranges to evaluate the feasibility of concentrating carbonaceous material through the flotation process. The tests were carried out on a bench flotation machine. The machine's agitator had a speed of 19.5 rpm and the flotation cell had a capacity of 0.75 l. The test products, concentrate and tailings, were subjected to ash and moisture tests. Through the results it was possible to notice that the lowest ash contents are in the coarser fractions, which is 1.0 mm, and the highest ash contents are in the feed less than 0.500 mm and less than 0.250 mm. The fraction with the greatest recovery potential is 0.250 mm with a percentage of 17.5% in mass of the recovered concentrate. In relation to the collector, the best carbonaceous recovery is found at a concentration of 10000 g/t, obtaining a maximum percentage of 79.1%.

Keywords : Charcoal Tailings, Charcoal Tailings Flotation, Tailings Concentration

I. INTRODUCTION

In the cement industry in Mato Grosso do Sul state in Brazil, the main fuels used in cement production are coke, charcoal, and tires (all of them as fine-grained material) [1]. Upon reaching the cement production plant, the coal must undergo sizing steps (crushing, grinding, and sieving). Coal, to be charged in the

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cement production furnace as fuel, needs to be fine enough to burn quickly and release a high amount of heat required by the process.

The coarser fraction (> 0.250 mm), which is product of sizing step is characterized by a high ash content (around 70% by mass of ash) and, consequently, a lower carbon content [1]. Nowadays, this material, as it has no use, is placed in landfills and discarded as waste. Although there is a high ash content, there is a relatively large amount of carbonaceous material contained in this material, reaching up to 20% [1].

To solve the problem, flotation stands as a process with potential for application, being an operation to separate materials from heterogeneous mixtures of suspended particles aqueous phase. [2] (Figure 1).



Figure 1: Schematic diagram of a flotation machine [3].

In this context, it is possible to concentrate carbonous material from charcoal, reducing its ash concentration, thus producing a material with suitable concentration (up to 20% ash) for use in cement production processes.

Charcoals are naturally hydrophobic materials, therefore, do not need the addition of a collector. However, collectors act as hydrophobicity reinforcers, which spread over the surface of the charcoal particle and increase the hydrophobicity, favouring flotation [2, 4-6].

The collectors used in coal flotation are diesel and kerosene [7]. These collectors adsorb in charcoal surface by adhesion or segregation, since oils have no affinity for the aqueous phase, depositing on the coal surface and, thus, reinforcing collection [7]. The adsorption of oil on the coal surface is achieved by physical adsorption, this segregation effect expels the oil molecules, joining in the phase with which they have the most affinity [7].

The most used frother in coal flotation are pine oil and methyl isobutyl carbinol (MIBC) [7]. Frothers may be either polar and non-polar molecules that have electrical attraction between the polar portion of the molecule and the mineral-bearing sites on the charcoal surface [7]. Pine oil has collecting properties, therefore, because its froth is consistent, it is able to carry carbonaceous particles [7].

Therefore, the theme of the work is the study of the feasibility of concentrating carbonaceous material through flotation. Thus, the work is based on the hypothesis that there is a set of collectors, different particle size ranges, frother and depressor that result in a product with suitable concentration.

The aim of the work is to evaluate the feasibility of using different concentrations of collectors and particle size ranges to evaluate the feasibility of concentrating carbonaceous material through flotation process.

II. METHODS AND MATERIAL

The experimental procedure of this work was performed in the Federal Institute of Mato Grosso do Sul (IFMS), Campus Corumbá, at the Laboratory of Metallurgy (LAMET).

The raw material used for this study was charcoal tailings supplied by a cement industry with an ash percentage on a dry basis of around 75%, by mass.



The flotation tests were carried out on a Lleida flotation machine. The machine was set with a propeller speed of 19.5 rpm and the flotation cell had a capacity of 0.75 l.

To perform the flotation tests, the samples were fractionated into 100 g batches, using 3 sieves with different openings (1, 0.500 and 0.250 mm). Three different collector (diesel) concentrations were used (100, 1000 and 10000 g/t). The frother concentration (pine oil) was 50,000 g/t. The conditioning time between adding the reagents was 5 minutes.

After conditioning, air was injected to form the froth, which was removed with a silicone spatula. The concentrate collection time was set to 15 minutes. Afterwards, concentrate and tailings were dried. The test products, concentrate and tailings, were subjected to ash and moisture tests.

The moisture content test was based on the loss of water by evaporation in an oven at a temperature of 105 °C for 2 h. The moisture content is measured using Eq. 1:

$$Moisture = \left(1 - \frac{m_f}{m_i}\right) \times 100\% \qquad \text{Eq. 1}$$

Where: m_i = initial mass of the sample [g]. m_f = final mass of the sample [g].

The ash content was determined by the remaining mass of charcoal after combustion of organic matter and oxidation of the inorganic constituents of the sample in a muffle furnace at 800°C for 1 h, according to Equation 2:

$$Ash = \left(\frac{m_f}{m_i}\right) \times 100\%$$
 Eq. 2

Where:

 $m_i = initial mass of the sample [g].$

 $m_f = final mass of the sample [g].$

The ash content values showed in the work did not take the moisture content into account, that is, the ash was calculated on a dry basis, therefore, the determination of the moisture content was used to discount the water mass, as shown in Equation 3:

Ash (dry basis)
=
$$\left(\frac{Ash}{100-Moisture}\right)$$
 Eq. 3
 $\times 100\%$

III.RESULTS AND DISCUSSION

From the experimental procedure presented in the previous section, the data depicted in Table 1 was obtained. The data, showed in Table 1, presents the results of the ash (dry basis) and the mass of the concentrate and tailings, in addition, it presents mass recovery values and carbon recovery from the performed tests.

TABLE I DATA ON MASS RECOVERY AND ASH CONTENT FROM CONCENTRATE AND TAILINGS.

		Concentrate		Tailings		Recovery	
F	С			М	А	Μ	С
[mm]	[g/t]	M [g]	A [%]	[g]	[%]	[%]	[%]
1,0	100	11,72	12,13	86,55	87,07	11,9	47,8
1,0	1000	12,54	17,31	84,50	86,49	12,9	47,7
1,0	10000	15,82	18,55	82,51	88,58	16,1	57,9
0,500	100	11,57	12,84	86,38	91,36	11,8	57,2
0,500	1000	13,75	24,19	83,75	96,30	14,1	77,1
0,500	10000	16,71	17,57	82,05	93,74	16,9	72,4
0,250	100	14,98	30,64	82,97	95,23	15,3	71,4
0,250	1000	14,29	31,03	84,39	95,25	14,5	70,9
0,250	10000	17,05	31,41	80,46	96,13	17,5	79,1



Labels: F – feed particle size (passant) [mm]; C – collector concentration [g/t]; M – mass [g]; A – ash content (dry basis) [%].

Through the results it is possible to notice that the lowest ash contents are in the coarser fractions, which is retained in 1.0 mm, and the highest ash contents are in the charge passant in 0.500 mm and lower than 0.250 mm. This indicates that there was greater selectivity in the tests carried out with coarser materials, which resulted in greater hydrodynamic collection in the results of finer particles. This is confirmed by the higher mass recoveries shown in tests with finer particle sizes. These trends reflect what has been observed in the literature [4-6].

Figure 2 shows the mass recovery in relation to the particle size from different collector concentrations. In Figure 2, larger particles presented lower recovery, compared to finer particles, where the best mass recovery is obtained. Therefore, it was possible to note that in the range of 0.250 mm (and 10000 g/t of collector) there is the best recovery data, reaching a percentage of 17.05%, while the range of 1.0 mm (and 100 g /t of collector) presented the lowest mass recovery across all different particle sizes with a minimum recovery of 11.57%.



Figure 2: Mass recovery versus particle size.

Based on these data, one of the keys to the success of flotation is the balance between a set of parameters, such as gravitational force (represented by the weight of the particles), bubble size and turbulence [8]. Coarser particles are harder to be carried by the bubbles due to their weight, which requires stable bubbles with larger sizes, meaning that smaller bubbles do not support the bubble-particle aggregate. Therefore, one of the flotation steps, transport, is undermined by the increase in maximum particle size. These behaviours are observed by several authors, both of basic texts [4-6] and authors regarding a similar study [8].

Figure 3 presents the results of mass recovery as a function of collector concentration. Through the data presented, it is observed that the greater amount of collector added, has a greater mass recovery, repeating the results in all particle size ranges, reaching a maximum recovery of 17.05%. In the smallest quantity, especially in the passant in 0.500 mm, the mass recovery is the lowest of all, reaching a percentage of 11.57%.



Figure 3: Mass recovery versus collector concentration.

The explanation for this phenomenon is the increase in the hydrophobicity of the coal particles. As the collector was added with the aim of enhancing the hydrophobicity of the coal particles, thus increasing the selection potential of coal particles, which are already naturally hydrophobic. This phenomenon has been described by a range of authors [4-6]. Furthermore, it is important to note that the more collector is added to the system, the greater the chance of particles that are not hydrophobic (in this case, ash components) to be covered by a collector film. As a result, the formation of less selective bubble-particle aggregates was noted, resulting in an increase in concentrate mass and ash content (Table 1). The collector saturation phenomenon was observed in flotation systems by other authors [4-6].

The results shown in Figure 4 show an increase in carbonaceous recovery with finer particle size, reaching a maximum percentage, at passant in 0.250 mm of 79.1% of carbonaceous matter. Furthermore, in coarser particles there was a decrease in the percentage of carbon recovery, reaching 47.7% in the passant in 1.0 mm.



Figure 4: Carbonous recovery versus particle size.

Based on these statements, it was shown that the finer the particle size, the greater the recovery of carbonaceous particles. However, the mass recovery of the material increased, resulting in higher ash contents. The results obtained can be explained based on two phenomena. The first is the liberation of the particles, which is, finer particles sizes reduce the possibility of mixed particles (of carbonaceous material and inorganic matter), this explains the results of greater carbonaceous recovery. The second phenomenon was the loss of relevance of gravitational forces in the flotation process. Therefore, the finer the material, the lower the relevance of gravitational forces, which is, the greater the chance of carrying the particles by turbulence inside the cell. Thus, the greater the probability of excessively fine ash particles being carried through cell turbulence, the higher the occurrence of inorganic matter in these materials. Both phenomena have been described by several authors [4-6].

Figure 5 shows the carbonaceous recovery results as a function of collector concentration. The results showed that the higher the collector concentration, the greater the carbonaceous recovery, obtaining excellent percentages of carbonaceous material recovered in the amount of 10000 g/t. At the lowest concentration, recovery decreases, reaching a minimum percentage of 47.7%.



Figure 5: Carbonous recovery versus collector concentration.

The increase in carbonaceous recovery with the increase in the frother concentration may be explained by the increase in the surface coverage of the particles capable of undergoing flotation. Therefore, the increase in concentration increased the hydrophobicity of carbonaceous particles, resulting in greater recovery of these particles.

It is important to note that the increase in surface area, caused by the decrease in particle size, may have increased the liberation of charcoal particles, resulting in less gangue material in the concentrate. These fine particles, in addition to increasing the selectivity of



the process, increase the demand for collectors. Therefore, it is believed that, in the case of coarser particles, the lower carbonaceous recovery happened due to the smaller liberation of carbonaceous particles, and the lower collector demand, which is consequence of the smaller surface area of coarse particles. Another relevant cause to be pointed is that transporting coarser particles is harder, since they are more susceptible to gravitational forces and the breakage of the bubble-particle aggregate due to turbulence.

The phenomena previously described and observed through Figure 5 have already been described by other authors [4-6, 8].

IV.CONCLUSION

Throughout the results it is possible to summarize the conclusions as it follows. Mass recovery is decreased by increasing feed particle size and is increased by increasing collector concentration.

Carbonaceus recovery is decreased by the feed particle size and is increased by collector concentration. The fraction which presents the highest recovery potential is the passant in 0.250 mm with 17.5% of the recovered concentrate. This fraction represents higher ash contents at a maximum percentage of 31.1%.

Regarding the collector concentration, the best carbonaceous recovery was found at 10000 g/t, obtaining a carbonous recovery of 79.1%. At this concentration, the mass recovery among the different particle size ranges is 17.05%, however, with the highest percentage of ash in the entire process with 31.41% ash content.

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