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Evaluation of materials from the excavation of the Ouenza hematite deposit (North-East Algeria) by gravimetric enrichment

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Abstract

Manuscripts should Quarries and mines that exploit hematite ore Fe_2O_3 usually have a large quantity of waste rock with low iron content, stored in the slag heaps of quarries or mines without enrichment. This work consists in finding solutions to this product to make it more or less usable in industries. After chemical and mineralogical analysis of the whole product, the large percentage of existing chemical elements is the hematite ore Fe_2O_3 which has a low iron concentration. To improve its iron content, it must be treated by chemical and hydro mechanical processes that are economically viable. Since it remains in the product heap, it will be degraded in the open air of the quarry by atmospheric chemical reactions. A certain amount of this stockpile is sampled at different locations in a heap to distinguish the chemical elements of the dominant product. The search for good enrichment techniques of these materials after their homogenization led us to choose among the main separation operations, those based on the difference of densities obtained by suspension in granulated Ferro-solutions composed of silicon and magnetite. From the results of the gravimetric separation, three fractions were obtained: an iron-rich fraction; a medium fraction; an iron-poor fraction <10%. According to the magnetic properties analysis, as a semi-separated product, the medium iron fraction will undergo a new enrichment sequence by high magnetic field separation.

Keywords: Separation, Hematite, Heavy suspension, Magnetic properties, Enrichment

Introduction

Prepare The requirements of hematite as a raw material in various companies and industries worldwide require very concrete parameters and properties of this material. The chemical loop combustion (CLC) process requires alternative oxygen carriers. Several studies and redox tests on some types of ores as oxygen carriers after beneficiation have been carried out by Mattisson et al. [1],interested in using hematite (Fe_2O_3) as a potentially usable oxygen carrier in the CLC process. The chemical analysis of the different samples showed that the ore of the studied deposit contains different types of materials, characterised by the presence of a large amount of waste rock that can be eliminated by gravimetric separation before their transport to the blast furnace of the metallurgical plant. Due to the continuous variation of the iron content of the extracted product due to the advancement of the deposit, homogenisation is necessary for the stability of its content around 55 %. This operation is currently carried out by mixing ore from four areas of the quarry to be studied. The mixture is made in proportions that determine its homogeneity before being transported to the factory. Today in world practice, hematite ore is widely used as a poor ferrous product, from which a concentrate is obtained with an iron content of 65-70 %, with a degree of extraction up to 90 %. for the (-0074) mm or (-0044) mm class. In the iron row, there is a content of calcite, magnetite and carbonate impurities. The red-brown carbonate group contains

a significant amount of hematite characterised by a fine partial smear at the grain ends of the carbon oxides. The gravimetric and then heavy slurry beneficiation process is one of the most accelerated separation systems, based on the preparation of separation and slurry products and the process of separating the heavy and light fractions.
In this study, the following scheme was chosen to separate the low-iron fraction of the ore from the quarry: The recovered particles are passed several times through the spirals of the screw separators to obtain a concentrate with an iron content about 65 %. The concentrate can be sold as is or sent to the plant to be agglomerated with a binder (like concrete) and then shipped to the steel mills. Self-melting pellets are also produced by adding dolomite. The main advantage of this process is the short processing time, which varies between 20 and 90 minutes. Sulphur dioxide (SO_2), on the other hand, presents a potential health risk to workers, so great care must be taken in its handling and storage.

General survey of the treated product

Mineralogical and chemical study of samples

Mineralogical and chemical analysis of the 10 samples from the slag heap stockpile showed us that samples N°1 and 2 contain practically pure hematite (90 % of the ore), particularly for N°1 the iron content is 62 %. The siderite has an iron content of 40-45 % in samples N° 9 and 10. Different mixtures of quartz an a chorite have iron content up to 20 % with hydroxide stains, i.e. almost only waste rock like samples N°(3; 4; 5; 6; 7) and 8. According to the quality and quantity of ore in a heap, for the proper enrichment technique of these homogenised materials, we divided the set from the feed into three technological types of different iron concentrations:

- Rich materials with an iron content of over 45 %
- Materials with an average iron content of 45 to 10 %
- Materials with an iron content of less than 10 %

After studying the mineralogical and chemical analyses results, we noted that this product should first be separated according to the gravimetric separation scheme. This results in a large quantity of sterile material, which can be used as building material at the quarry without transporting it to the plant. The separation principle chosen is based on the difference in densities of the three fractions obtained by suspension, granulated ferrosilicon and magnetite. Density separation is a physical separation method [2,3]. This physical approach makes it possible to limit chemical interactions [4,5]
The density of the dense liquor is an essential parameter to know before implementing the method[6]. The hematite Fe_2O_3 content required by global companies and corporations, especially by the cement industry as a tinsel product, is 1 to 8%. This study considers this parameter which is of great importance[2].
Table 1. represents the density of each product used for the gravimetric separation of our product composed of hematite. Separation according to density is possible given the density of the hematite which is 5420 kg.m^{-3}.

Table1. Limit values of raw cement components in the foil [2].

Oxydes	Limit %	Average value %
CaO	60 – 69	65
SiO_2	18 -24	21
$A1_2O_3$	4 - 8	6
Fe_2O_3	1-8	3
MgO	< 5	2
K_2O, Na_2O	<2	1
SO_3	<3	1

Magnetic properties of iron ore from Ouenza deposit

The tests on the magnetic properties for the samples of the semi-finished product fraction (of gravimetric separation)led us to obtain the following chemical analysis results.

Table 2. Result of chemical analysis of the semi-finished product.

Chemical compounds	Fe	FeO	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	TiO_2
Content β ,%	41,6	0,3	59,3	8,2	0,65	10,1	2,4	0,04

The minerals that contain the most iron in these samples are hematites and siderites, with a maximum content of 38%. The waste rock of all the other samples includesdolomites with quantities of quartz, 15% ankerite and 12.3% pyrite. The magnetic properties were determined by the Gouy method [7-9]. For this purpose, the product was crushed to 76.7 % of the -0.074 mm class. The results of the measurements are presented in Table 3.

Table 3. Magnetic properties of the classes characterising the stored product.

Fraction size µm	Density of the fraction $kg.m^{-3}$	Coercive force $kA.kg^{-1}$	Remnant magnetisation (remaining) $kAm^2.kg^{-1}$	Specific magnetic susceptibility for $H=238,85\ m^3.kg^{-1}$
-100+74	1,58	35,82	104,28	1,59
-74+44	0,98	50,15	45,71	0,98
-44+20	2,38	74,84	152,85	2,38
-20+0	2,02	37,26	111,42	2,02

Table 3. clearly shows that the magnetic susceptibility increases with decreasing particle size of the minerals. The samples has a negative influence on their magnetic properties and mineral bonding. Mineral samples that contain less iron have weak magnetic properties and can undergo high-intensity magnetic field separations. The development of magnetic separation of this type of particle is based on improving its field gradient H, in [$kA.m^{-2}$] where H is the magnetic field strength in ($kA.m^{-1}$). Experiments show that even for small values of magnetic field intensity, wire wool allows sufficiently good extraction of strongly magnetic particles from the pulp [6].

On the other hand, the complex and microporous structure of the metal wool does not favour the release and passage of the pulp, nor the washing of the magnetite particles under industrial conditions that are carried out under high water pressure, which is costly. In addition, due to the magnetic field's constant reorientation, the particles in a relatively free state on the surface of the accumulated layers acquire a torque moment. In case of additional water supply, the rotation facilitates the removal of weak magnetic particles and waste, increasing the concentrate's quality. The details and description of this phenomenon of rotation of magnetic particles in the alternating magnetic field were described by Allen [6,7].

Materials and Methods

The method used to determine the iron content of the hematite powders of the ten samples is the bichromatic titrimetric method, which is based on the reduction of ferric iron with a chemical solution of stannous chloride and a solution of titanium trichloride in an acidic medium. Hydrochloric acid in a ferrous medium, followed by titration of the latter with a solution of potassium dichloride in the presence of sodium diphenylamine sulfonate as an indicator.

The expressions used characterize the mass fraction of total iron XFe in percentage which is calculated by the following formula:

$$\mathrm{XFe} = \frac{\mathrm{C(V - V1).100.K}}{\mathrm{m}}$$

Where;

C: Mass concentration of potassium dichromate solution for iron ($g.cm^{-3}$);

V: Volume of potassium dichromate solution consumed for titration of the analyzed solution (cm3); V1: Volume of potassium dichromate solution for solution titration (cm^3);

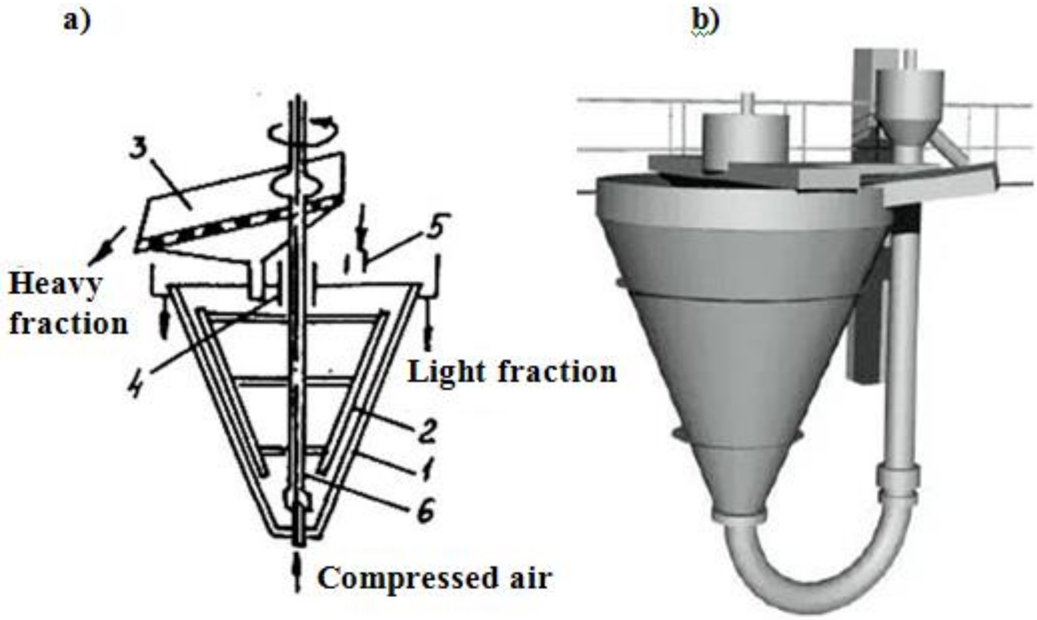
M: Mass of the sample (g);

K: Conversion factor of the mass fraction of total iron to its mass fraction in dry matter.

Method and materials used for separation into heavy suspensions

The quantity taken from the quarry heap has undergone primary enrichment by the pneumatic cone separators see Figure1 separators of this type are used for the enrichment of ores and non-metallic minerals. They are equipped with an internal compressed air elevator. This figure shows this CK4 type cone separator with a productivity of 40 to 63 T/H.

Figure 1. Diagram of the cone separator



a) kinematic diagram:

1-body; 2 mixers; 3 arched screen; 4 axial funnel; 5 feed chutes, 6 rotary axis.

b) switchgear diagram

Inside the conical volume 1 of the separator on the hollow shaft 6, a mixer 2 turns. The original ore is fed by the loading chute 5 and is subjected to stratification in a suspension fed by an axial funnel 4 . The heavy fraction of the ore is immersed in the lower part of the cone. Then using a compressed air elevator, it is unloaded at the top on a chute, at the bottom of which are installed arched sieves 3. is dumped and returns to the separating part of the conditioned heavy suspension. The light fraction is discharged from the separator through an adjustable threshold on the side of the cone by an overflow with part of the slurry and is sent for separation and washing through sieves.

Table 4 represents the density of each product used for the gravimetric separation of our product composed of hematite. Separation according to density is possible given the density of the hematite which is 5420 $kg.m^{-3}$.

Table 4. Characteristics of suspensions used in ore separation.

Suspension element	Suspension density $kg.m^{-3}$	Maximum possible suspension density $kg.m^{-3}$
Ferro-silica granule 90 % spherical particles containing 85 % iron 15 % per Si	6900	3600 - 3900
Magnetite	5000	2500

The density of the dense liquor is an essential parameter to know before implementing this separation method [6].

Results and Discussion

The results presented in Table 5. show the large difference between the hematite Fe_2O_3 contents in the two heavy and medium density fractions which are respectively equal to 64.8% and 59.2% with that of the light fraction which is 9,9 % .

Table 5. Chemical analysis of three fractions of different densities.

Fraction		**Heavy**	**Medium**	**Light**
Compound content, in %.	Fe	45 .6	14.6	7.1
	FeO	0.4	0.3	0.3
	Fe_2O_3	64.8	59.2	9.9
	SiO_2	7.8	8.2	9.0
	Al_2O_3	0.7	0.65	0.5
	CaO	8.4	10.1	37.0
	MgO	2.0	2.4	10.1
	P_2O_5	Tracks	Tracks	Tracks
	S	0.018	0.04	0.022
	TiO_2	0.01	0.04	0.02
CaO/ SiO_2 Ratio in the fraction		1.07	1.23	4.11

Table 6 shows the particle size characteristics of the separation product obtained by sieving the homogenized hematite product brought back from the pit of 38.7% content. which shows the distinction in iron content between the classes chosen for the treatment.

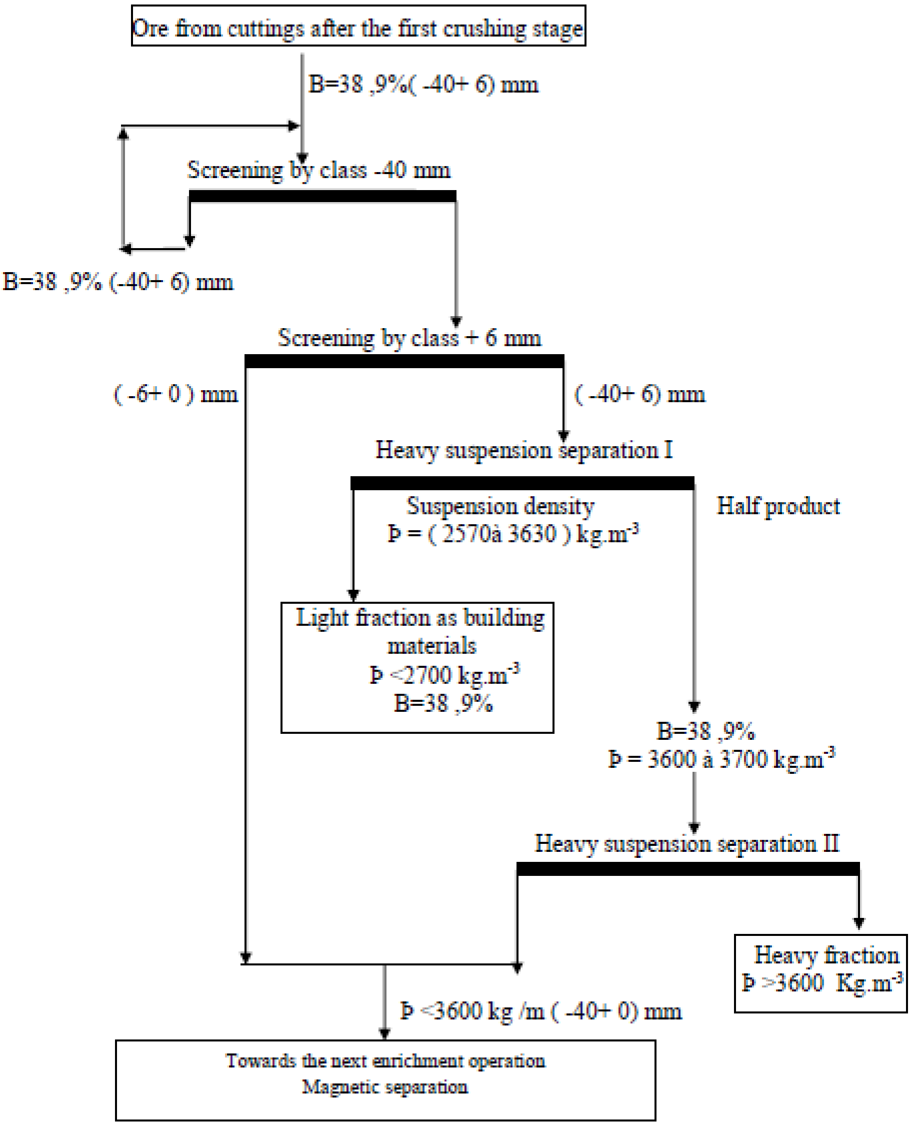
Table 6. Sieve analysis of Ouenza ore feed with iron content, ß= 38.7%.

Class size mm.	Class performance (%)	Iron content %	Degree of extraction %
-100 + 40	65.1	39.9	65.4
-40 + 10	15.2	36.1	14.21
-20 + 6	6.4	41.6	6.91
-6 + 0	13.3	39.3	13.5
Sum	100.0	38.7	100.0

In this study, we determined the principles of using different enrichment methods under the specific conditions of the semi-desert zone of the deposit.

Figure 2 is an enrichment scheme chosen from among several variants depending on the specific conditions of the semi-desert zone of the deposit. This scheme is composed of two screening steps and two separation steps in heavy suspensions. The screening is carried out in two stages until obtaining the -6 + 0 mm class which is not rich which will be directed towards storage and the -40 + 6 mm class which will undergo enrichment operations. The -40 + 6 mm class will be directed to the first stage then to the second stage of separation by suspension. After these operations, the three fractions indicated in Figure 3 are obtained.

Figure 2. Gravimetric enrichment technological scheme



Where;
Þ: density of the product kg.m^{-3}
B:iron content %

Hydrated lime $Ca(OH)_2$ is the reagent generally used to raise the pH of the water and thus precipitate heavy metals in solution as metal hydroxides. Mine water can be reduced either underground, before pumping to the surface, or before discharge to the settling pond. Suspended solids in the mine water are removed by settling in the pens. If necessary, sedimentation ponds are built downstream of the pens to improve treatment. If necessary, flocculants can be added. The presence of colloidal iron is at the origin of the red water that can be observed in some iron mines. These colloids have been treated for several years at the Company Miner Québec Cartier site in Fremont. The addition of polymers in a series of tanks allows the formation of flakes that precipitate the mixtures in a settling tank. The sludge resulting from this sedimentation is then pumped into the settling tank.

Conclusion

The mineralogical and chemical compositions of the core of the homogenised slag heap were studied with the determination of its classification into three types of ore:

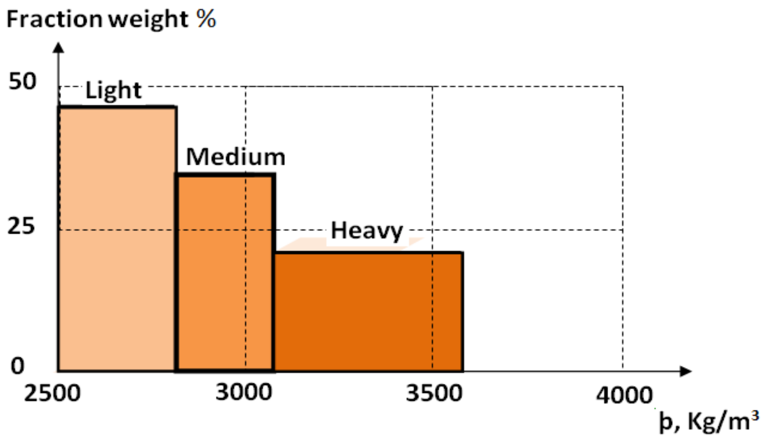
a) Rich ore up to 91% hematite with iron content up to 62 %
b) Siderite ore with iron content up to 15 %;
c) Ankerite and quartz with iron content up to 20% in the form of hydroxide stains almost entirely from waste rock.

In this study, we determined the principles of using different beneficiation methods in the specific conditions of the semi-desert zone of the deposit. It can be noted that there is a possibility of ore beneficiation by the proposed methods with determined sizes of the product of each concrete beneficiation method.

From the results of Figure 3 and the results of the mineralogical and chemical analyzes, we can conclude that the average fraction or the semi-finished product which is not rich enough should be separated according to the gravimetric separation scheme as a first step. This provides a large amount of waste rock, which can be disposed of first for use as construction material at the quarry level, without transporting it to the plant. This type of gravimetric separation allowed us to extract nearly 45 % in light fraction not very rich in iron, then up to 35 % in average fraction at medium content and nearly 20 % in heavy fraction very rich in iron. The principle of separation chosen is based on the difference in density of the three fractions obtained by the suspension, the granulated ferrosilicon and the magnetite.

Due to the low iron content of this part, which contains barren material, its homogenisation is very important to be suitable and acceptable for smelting. For effective use of the part stored in the slag heap with iron content below 20 %, we started by studying some samples, 10 in number, brought from the quarry with the agreement of the group of geologists in place. A scheme of ore beneficiation after homogenisation was proposed with concrete values of separation indices for each process and each procedure. The enrichment values were then determined qualitatively and quantitatively. The technological scheme gave perfect results that meet the beneficiation requirements and ensure minimum loss of useful ore during processing.

Figure 3. Dependence of the percentage of the fractions obtained on their densities ($Kg.m^{-3}$)



CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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