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NEW METHOD OF ELECTROSTATIC SEPARATION OF THE OXIDIZED IRON ORE

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Abstract: The complexity of the mineralogical, chemical and exogenous parameters generates a low efficiency of electrical separation of oxidized iron ore. For this purpose, a study was conducted to provide a method for electrostatic separation and to select the chemical reagents. And this, for increasing the contrast of the dielectric separating minerals in the corona discharge field. The reagent-collector used is the auramine with a specific consumption of 0.3 kg/t. Whereas, the reagent depressants is carboxymethyl cellulose mixture with a specific consumption of 0.25 kg/t. From the obtained test results electrical treatment of oxidized iron ore are satisfied for proposed process.

Keywords*: iron ore, electrostatic separation, reagent-collector reagent – depressant, efficiency*

INTRODUCTION

The deposit of Ouenza (Algeria) is the main ore mining iron pole in the country. This field produces about two million tons of ore per year in which 70% are above the 55% level. The rest of the quantity of contents is generated varying from 42-50%. This is a poor ore stored at the mine and requiring treatment.

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The development of these minerals will increase a share of industrial reserves of the deposit, on the other hand safeguarding the environment which is considered a major challenge for the region.

The method of electrical separation is based on the use of the difference in electrical conductivity of minerals to be separated. However, this conventional method has limitations resulting from low separation efficiency. The present study was conducted to provide a method for electrical separation using chemical treatment reagents and reagent -depressants collectors thereby increasing the contrast of the dielectric separating minerals.

STUDY OF THE TECHNOLOGY CONCENTRATION BY ELECTROSTATIC

The study refers to a concentration technology of electric oxidized iron ore at Ouenza iron ore deposit. It is well known that the electrical isolation is based on the use of the difference in electrical conductivity between the minerals to be separated (Dumitran et al., 2007).

The objective of the study is to increase the separation efficiency of oxidized iron ore. This can be achieved by increasing the contrast of the dielectric separating minerals.

The main processes of electric charging of the particles are in the electrical separation ionization (corona charging, α – β radiation), the electrification by friction, contact with the charged electrode, induction heating, combination of raising processes (two or more).

Among these processes, the greatest interest is in the field ionization discharge ring (Dumitran et al., 2005).

Consider the highest electric charges received by the same particle in the field of corona discharge due to contact with a rotating cylindrical surface, grounded.

The dependence of the load value is defined by the formula Potenier (Pauthenier et al., 1932).

$$Q_\tau = 4\left(1 + 2\frac{\varepsilon-1}{\varepsilon-2}\right) E_\tau^2 \frac{e\, n\, k_n \tau\, \pi\, \varepsilon_0}{4\varepsilon_0 + e\, n\, k_n \tau} \quad (1)$$

k_n – mobility ion, (m^2/vs)
ε – relative dielectric permeability of the material;
n– number of elementary charges;
ε_0 – dielectric constant, $8.85 \cdot 10^{-12}$ F/m ;
τ – time, Sec;
e – particle charge, e = $1.6 \cdot 10^{12}$ C;
E – electric field strength, kV/cm

The maximum value is obtained when

$$Q_{max} = 12\pi\varepsilon_0\tau^2 E\left(\frac{\varepsilon}{\varepsilon+2}\right) \quad (2)$$

For a conductive particle, considering where:

$$Q_{max} = 12\pi\varepsilon_0\tau^2 E \quad (3)$$

Considering that in the electrical load, the field strength and the particle size are sufficiently high and, thus, it is possible to neglect the small influence of the thermal motion of ions.

The load value of the particle as a function of exposure time in the wrong field is determined from the formula (1). The maximum load is equal to:

$$q_{max} = \pi\varepsilon_0\left(1 + 2\frac{\varepsilon-1}{\varepsilon+2}\right)E_c d_r^2 \quad (4)$$

Under the condition: $q/q_{max} = 0.9$

The time of exposure of particle in the field of ring (calculated) is equal to:

$$\tau = \frac{36}{nek} = 0.12 \text{ seconde}$$

where:

ε, d_r −dielectric permeability and particle diameter;

E_c −electric field intensity of the crown;

n, k – concentration and mobility of ions;

ε_0 −dielectric constant, $8.85\cdot10^{-12}$ F/m

e – electron charge, $e = 1.6.10^{12}C$

$\tau = \frac{H_c}{\vartheta}$ − exposure of the particles in the field of ring time.

The exposure time of the particle in the field of ring (measured) is equal to:

$$\frac{\mathrm{H_c}}{\vartheta} = 0.10 \text{ second}$$

where:

H_c −crown height field (m/s)

ϑ – velocity, (s)

Note: the values of both exposure times – calculated and measured – are practically very close (0.12/0.10 seconds).

All particles receive, in the field of the ring, the load:

$$q_0 = 0{,}9\pi\varepsilon_0\left(1 + 2\frac{\varepsilon-1}{\varepsilon+2}\right)E_c d_r^2 \tag{5}$$

In this work, the study is focused on the process of loading a crushed during its movement by the troughs and metal dielectric material (Mihai Bilici et al., 2011). The results show that the quartzite of diameter 60 μm receives a load of about 10^{-17} C, the same particle receives current field crowned load $Q_{max} = 10^{-13}$ C. This represents an increase of 10^4times.

The value of triboelectric charge of the separated particles reaches a certain percentage of loading in the region of a normal discharge crowned.

Therefore, there is a possibility to use fillers for the separation of friction of certain ground materials. The separation corona charging field is an advantage with respect to tribo-charging method (Dumitran et al., 2005, Tilmatine et al., 2009).

We evaluate how different the charges received by the quartz and hematite ring field of the same intensity (Tiberiu et al., 2010).

The calculation of these values of loads is as follows:

$$\frac{q_0}{E_c} = 0.9\pi\ \varepsilon_0\left(1 + 2\frac{\varepsilon-1}{\varepsilon+2}\right)d_r^2 \tag{6}$$

$$Q = \frac{\Delta\frac{q_0}{E_c}}{\frac{q_0}{E_c}} = \frac{2\left(\frac{\varepsilon_h-1}{\varepsilon_h+2} - \frac{\varepsilon_q-1}{\varepsilon_q+2}\right)}{1+2\frac{\varepsilon_q-1}{\varepsilon_q+2}} \tag{7}$$

where $\varepsilon_h, \varepsilon_q$ – relative dielectric permeability of quartz and hematite.

Knowing that the dielectric permeabilities for hematite and quartz are equal to: $\varepsilon_h = 81, \varepsilon_q = 6.5$, we obtain $Q = 27.6$ %. This value is to be used in the separation of a poly-dispersed material (Bilici et al., 2011).

To compare the effectiveness of different methods of loading particles "fluidized" layer, the first value of the specific charge of particle is determined to be evaluated according to the following formula:

$$\frac{q_0}{m.E_c} = \frac{6\varepsilon_0}{0{,}9\ \rho_r}\left(1 + 2\frac{\varepsilon-1}{\varepsilon+2}\right)\frac{1}{d_r}$$

where m, ρ_r – Mass and density of the particle (Kg, Kg/m^3).

From the formula above, it is deduced that the greater particle size decreases, the specific electrical load increases.

The discharge mechanism of the particles in the field of the corona discharge is shown in Figure 1. In the presence of sufficiently high voltages applied in the space between the electrodes, with the surface of the corona electrode, is made of the intense shock ionization of gas accompanied by the appearance of the load ring and s '

attenuates gradually as the decrease in the intensity of the electric field in the direction of the collecting electrode (Medles et al., 2011, Tabti er al., 2010).

Gaseous ions of different polarities formed in the crown area under the action of an electric field (Coulomb force), move to the electrodes of opposite polarity. However, in the inter – electrode forms the electric current of said crown. The ore particles receive, due to the absorption of ions onto their surface an electric charge in the inter–electrode (Tiberiu et al., 2010, Bendaoud et al., 2010).

The loading of particle increases until the ions do not couple with each other. By increasing loading time and the number of ions deposited on the particle, increasing the intensity of the field created by the charged particle is directed towards the outside of the main field intensity. When these intensities become equal, the particle stops receiving new ions. Therefore it will stop charging. At this time, the particle has the maximum possible charge (Younes et al., 2010, Tabti et al., 2009).

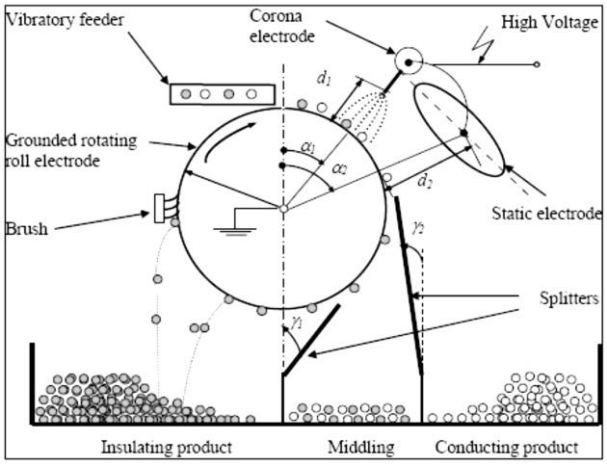

Fig. 1.The loading mechanism in the field of ring (Dumitran et al., 2007)
$\alpha_1$et d_1 – angular and radial positions of the corona electrode;
α_2 et d_2 – angular and radial positions of the electrostatic electrode;
γ_1 et γ_2 – angular positioning of dividers.

EXPERIMENTAL

The study of the samples mineralogical composition of iron ore is carried out by metallographic microscopy of polished sections (see Table 1).

Chemical analysis by XRF show the poverty iron ore deposit of the above-mentioned (see Table 2) (Idres et al., 2005).

The oxidized iron ore is ground and dusted heated to a temperature of 120 to 150°C. The latter is treated with the reagent by aerosol – auramine manifold that is

heated to a temperature of 80 to 90 °C, and followed by the electrochemical treatment at a voltage of 10 Volts. The fixation-depressant reagent on the surface of the gangue minerals and provides surface protection against moisture and increases the dielectric properties of sterile particles. As reagent – depressant, was used and the mixture of Carboxymethyl cellulose nitrolignine whose ratio corresponding to (20–25)/ (80–75).

Tab. 1. Mineralogical composition of the iron ore to the low levels of Ouenza

Minerals and rocks	Content, %									
	H	G	H G	SA	D	C	Q	A	M A	Other
Hematite-hydrogoethite	12.18	40.29	29.17	8.07	1.56	4.12	2.41	0.08	0.12	2.00
Goethite-hydrogoethite	3.09	19.38	50.17	7.79	3.35	5.13	9.05	0.12	1.05	1.57
Limestone	0.17	0.28	0.97	-	-	94.37	1.30	-	-	0.73
Sandstone	-	0.39	0.27	-	-	3.29	94.92	-	-	0.32

H – Hematite, G – goethite, HG – Hydrogoethite, SA – siderite-ankerite, D – Dolomite, Calcite – C, Q – Quartz, A – Apatite, MA – Clay minerals.

Tab. 2. Chemical composition of the iron ore to the low levels of Ouenza

Minerals and rocks	Fe t.	SiO_2	Al_2O_3	CaO	MgO	MnO	Mn	K_2O	Na_2O	P_2O_5	S	CO_2	p.p	Σ
Hematite	54.0	2.4	0.22	6.83	1.67	0.94	0.70	0.03	0.02	0.03	0.035	6.6	10.7	99.80
Goethite	41.7	22.5	0.30	13.35	1.06	1.85	1.43	0.03	0.19	0.06	0.02	6.2	18.1	99.72
Limestone	0.9	2.0	0.16	52.85	0.55	0.08	0.07	0.02	0.06	0.01	0.022	42.4	42.5	99.56
Sandstone	0.06	94.5	0.31	1.38	0.1	0.03	0.001	0.02	Tr.	Tr.	Tr.	1.86	1.93	98.35

The particle temperature before treatment with aerosol must be 120 to 150°C. While the reactants, it ranges from 80 to 90°C. In addition, during treatment with reagent-collector, the ore is subjected to electrochemical treatment for five minutes with a voltage of 10 Volts.

The auramine $C_{12}H_{25}NH_2$ with a molecular weight of 188.35 and melting temperature of 28.32 °C., represents a derivative of ammonia, wherein one or more hydrogen atoms are mixed with the aliphatic or heterocyclic radicals.

The ionic micelles have a nonpolar structure whose ends are directed towards the center, whereas the NH_2 groups represent a layer. Following this ionic micelle structure, the amines have an electrical conductivity (Andersen, 1995).

The carboxymethyl cellulose is cellulose ether and containing the carboxyl which is obtained by means of interaction of the cellulose with the alcohol of sodium salt of the monochloro acid vinegar (Samant et al., 2006).

$$[C_6H_7O_2(OH)_2ONa]n + nCl\,CH_2COOH \rightarrow [C_6H_7O_2(OH)_2OCH_2COONa]n + Na\,Cl$$

The nitrolignine is a mixture of calcium salt of lingo sulfonic acid addition sugars and minerals. It is obtained as industrial waste cellulose paper. The selectivity of binding of the reagent manifold and the reagent depressant on gangue minerals and metal are provided by the physico-chemical nature of the reagent and the mineral. The electrical treatment increases the collector reagent physicochemical binding activity on the metal inorganic (Butunoi et al., 2010).

Tab. 3. Indexes of testing electrical separation of oxidized iron ore

Processes of separation	Temperature heating		Collector reagent consumption kg/t	Report Carboxyl methyl cellulose / consumption kg/t	Consumption electrical energy, U/t	Technological Indices			
	Reagent	Ore				Performance of concentrate,%	Iron content %	Recovery %	Efficiency %
Classical process	-	120	-	-	-	35.0	50.0	47.3	19.5
	-	150	-	-	-	35.7	51.6	49.8	22.4
	-	170	-	-	-	36.0	52.1	50.7	23.3
	-	180	-	-	-	35.5	52.1	49.9	23.0
	-	190	-	-	-	34.8	52.0	48.9	22.4
1. Optimization of reagent consumption collector									
Proposed process	80	150	0.1	-	10/5	37.4	55.0	55.6	28.9
	80	150	0.2	-	10/5	37.9	56.2	57.6	31.2
	80	150	0.3	-	10/5	38.2	57.8	59.7	34.1
	80	150	0.4	-	10/5	37.2	57.8	58.1	33.2
	80	150	0.5	-	10/5	35.1	57.6	54.6	31.0
	80	150	0.6	-	10/5	35.1	57.5	54.5	30.9
2. Optimization of consumption and carboxymethyl cellulose nitrolignine									
	80	150	0.3	20:80 (0.1)	10/5	40.1	57.9	62.8	36.0
	80	150	0.3	20:80 (0.2)	10/5	42.0	58.0	65.8	37.8
	80	150	0.3	20:80 (0.3)	10/5	44.0	58.2	69.2	41.3
	80	150	0.3	20:80 (0.4)	10/5	46.3	58.6	73.3	42.9
	80	150	0.3	20:80 (0.5)	10/5	45.0	58.6	71.3	41.7
	80	150	0.3	20:80 (0.6)	10/5	44.6	58.4	70.4	40.9
	80	150	0.3	10:90 (0.4)	10/5	45.1	58.0	70.7	40.6
	80	150	0.3	15:85 (0.4)	10/5	45.3	58.3	71.4	41.4
	80	150	0.3	25:75 (0.4)	10/5	46.3	58.5	73.2	42.7
	80	150	0.3	30:80 (0.4)	10/5	45.8	58.2	72.0	41.6
3. Optimization of the heating temperature of the ore and reagents									
	60	100	0.3	-	10/5	45.3	58.1	71.1	41.0
	70	110	0.3	-	10/5	45.6	58.1	71.6	41.3
	80	120	0.3	-	10/5	46.1	58.3	72.6	42.1
	90	150	0.3	-	10/5	46.1	58.4	72.8	42.3
	100	160	0.3	-	10/5	46.1	58.1	72.2	41.6
4. Optimization of electrochemical reagent depressant treatment									
	80	150	0.3	-	10/1	41.1	57.8	64.2	36,.7
	80	150	0.3	-	10/3	42.9	57.9	67.1	38.3
	80	150	0.3	-	10/4	43.8	58.1	68.8	39.6
	80	150	0.3	-	10/5	46.3	58.3	72.6	42.1
	80	150	0.3	-	10/6	45.4	58.2	71.4	41.3
	80	150	0.3	-	10/7	45.0	57.0	69.3	38.6

The greatest effect of increasing the separation efficiency of the electric oxidized iron ore is achieved during processing of ore heated at a temperature of 120 to 150 °C and 80 to 90 °C reagents. The relationship between Carboxymethyl cellulose and nitrolignine is obtained on the basis of experimental tests.

The comparative test results of the methods of electrical separation of oxidized iron ores according to the conventional embodiment and the one proposed are shown in table 3.

RESULTS DISCUSSION

Experimental tests on oxidized iron ores are done at the Laboratory of Physical Metallurgy and Materials Properties, University of Annaba – Algeria. The sample of iron ore weight 1.380 kg of a size +5 – 0 mm, is grounded in a ball mill with a capacity of 7 liters. The size of the crushed ore is 70% of less than 0.25 mm wafer. The ore is deslimed in a cyclone diameter of 150 mm. Ore processing at the electrical electrostatic separator ring drum type PS-1 is made in two patterns: classic and proposed.

According to the conventional scheme, the ore is heated to a temperature of 150 to 170 °C and passed directly to the electric separator. While, for the proposed scheme:

- ore is heated to a temperature of 120 to150°C
- treating the already heated by itself heated to a temperature of 80–90 °C and electrochemically reactive ore collector.

CONCLUSION

This study highlights the importance of the chemical treatment before the operation of electrostatic separation; this allows us to conclude generally that:

1. As collector reagent, is used and auramine -depressant reagent (mixture of carboxymethyl cellulose and nitrolignine). The consumption of the reagent – manifold is 0.25 kg/t, and 0.30 kg/t to the reagent – depressant.

2. The aerosol treatment of heated ore ensures fixation on the surface of minerals and increases contrast in electrical properties between minerals and gangue. This contributes to a considerable increase of the separation efficiency of the electric iron ore.

3. Treatment of experimental tests gives respectively a separation efficiency of 23.30 % of the conventional method and of 42.90 % for the proposed method.

4. Considering the obtained results, the proposed method improves the separation efficiency of 1.84 times compared to the conventional method.

5. To improve the efficiency of electrostatic separation in the case of deposit of iron oxide ores at low levels, it is recommended to use chemical reagents

such as auramine and the mixture of carboxymethyl cellulose and nitrolignine prior to electrostatic separation.

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