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Dependence of the minimum charge of particle of induction charging on the electric field in the model condenser of an electric separator

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Abstract. This article deals with the method of mineral particles separation according to their electric conductivity. This process was carried out in the model condenser by induction charging and dependence of the minimum charge of the particles breaking away from the charging electrode on the electric field strength was studied.

Comparison of obtained results with the theoretical calculation shows that, from the three forces – adhesion, gravity and electrical acting on the particles, adhesion force, acting between the particles and electrode, can be neglected in case the minimum charge of the particle breaking away from the electrode, because the particles in this case have no time to change the orientation.

Key words: Adhesion force; depolarization; electrical separation; minimum charge; orientation of particles.

Introduction

Recently, a strong electric field is widely used in technological processes among methods of mineral reaching, in particular in electron-ionic technology (EIT).

EIT processes are widely applied in electric separators, where particles separation takes place according to different physical properties. Among these, particles separation according to electric conductivity during their induction charging, is very often used [1]

Efficiency of electric separation is related to determination of forces arising during induction charging. To analyze processes taking place on the electrode charging the electric separator during induction charging, it is better to view particles charging and forces acting on them in a uniform field of a plane condenser and generalize obtained results for a real electric separator.

Main part

The balance of the forces acting on the particles in a uniform field can be written as follows:

$$F_{el} - F_{gr} - F_{ad} = 0$$

Where F_{el} - electric force, F_{gr} - gravity force, F_{ad} – particle adhesion force with electrode.

Electric force acting on particles is defined as a force arisen by acting of bound charges, formed as a result of particles polarization in an electric field, which reaches its peak at the beginning of charging, also by action of free charges. After polarization, formed free charges interact with own reflection and because of this total force acting on particles is calculated as follows:

$$F_Z = \pi bc\varepsilon_0 E^2[\frac{0,5(\varepsilon_1-1)^2(1-I)}{K^2} + \frac{d_a\varepsilon_1^2-(d_a-I)\varepsilon_1+(1-I)}{K^2}\cdot\beta + \frac{0,5d_a^2(\varepsilon_1^2-1)+d_a-0,5I}{K^2}\cdot\beta^2],$$

Where F_z - force acting along the vertical axis

b,c – semiaxles of particle equivalent to ellipsoid

ε_0 - dielectric constant

E – electric field strength

K, β and I are defined as follows:

$$K=1+(\varepsilon_1-1)d_a,\ \beta=\frac{q_{fr}}{\pi bc\varepsilon_0 E},\ I=\frac{1}{\pi bc}\int_{S_1} cos^3\Theta d_s,$$

Where d_a – depolarization coefficient

S_1 – particle surface area excluding area of particle contact surface with electrode

Gravity is defined as follows:

$$F_g = mg = \frac{1}{2}\cdot\frac{4}{3}\pi\cdot a_{h\,el}\cdot b_{h\,el}\cdot c_{h\,el}\cdot\gamma_p\cdot g$$

Where γ_p - particle density

g – gravitational acceleration

$a_{h\,el}\cdot b_{h\,el}\cdot c_{h\,el}$ - semiaxles of ellipsoid equivalent to particle volume

Assuming that adhesion force is zero, then particle breaks away from charging electrode with its minimum free charge magnitude.

One of the important issues is to determine along which semiaxle particle lies on the electrode. In the initial stage the particle lies on the electrode in the most likely, comfortable and stable position. This is with a minor semiaxle along the field vector [fig. 1]. With this orientation particle perimeters are: $a_{h\,el} = 2c_{h\,el}$, $b_{h\,el} = a_{el}$, $c_{h\,el} = b_{h\,el}$. The coefficients are determined according to these data:

$$\beta=\frac{b_{h\,el}}{a_{h\,el}},\ \gamma=\frac{c_{h\,el}}{a_{h\,el}}.$$

Coefficient of depolarization d_a is determined by means of these coefficients.

Later on, while charging particles, shape of which is not strictly symmetric, it is under the action of rotating moment. Because of this, it begins rotation and orientates with its major semiaxle along the vector of an electric field (Fig.1_c). This phenomenon is confirmed both visually and by distribution of the particles breaking away probability function [3]. Accordingly, particle can break away from the electrode during any position shown on fig.1.

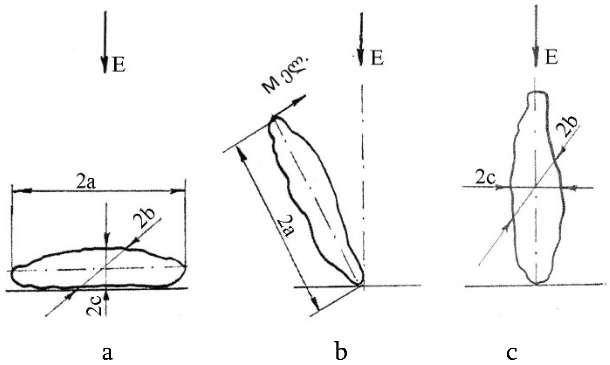

Fig. 1. Orientation of the particle positioned on the electrode in the electric field

To determine coefficient I analytically it is necessary to turn real semiellipsoid into rotating semispheroid i. e. into spheroid. This requires $b_{h\,el} = c_{h\,el} = \sqrt[2]{b_{el}}\cdot c_{el}$. At this time, the main determining parameter magnitude value of the main semiaxle directed along the field is retained, but the change of the two others by their average geometric values for real particle, gives 3-4% error.

Accoridng to the obtained specific parameters points, it is possible to determine theoretically minimum charge magnitude for a particle breaking away from charging electrode.

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Such measurements were practically carried out as follows: from conducting fraction of rutile was selected the three groups of particles. Each of which contained 10 particles about of one size-minor, mean and large. Average radius of each group was calculated as equivalent radius to sphere as follows a_(eq sp) = ∛(a_el)·b_el·c_el. Particle average magnitude in each group fluctuates within 7-8%. Ten particles of one of the groups were placed into the central part of the flat condenser charging electrode. Experiments were carried out in five series i.e. initial number of particles was 50. When high voltage was supplied, particles after being charged broke out from the lower electrode directing to the upper electrode.

As the surface of upper electrode was covered with a thin layer of insulation, charged particles sticked and stayed on them. We removed them by the use of a thin plate and put into charge measuring electrometer.

Minimum measured charge values for one of the groups of the particles, in case of different field strength values, are given on fig.2. Their theoretical values for different orientation of particles are also given (Fig.1_a and Fig.1_c). The same results were obtained for the rest of particles.

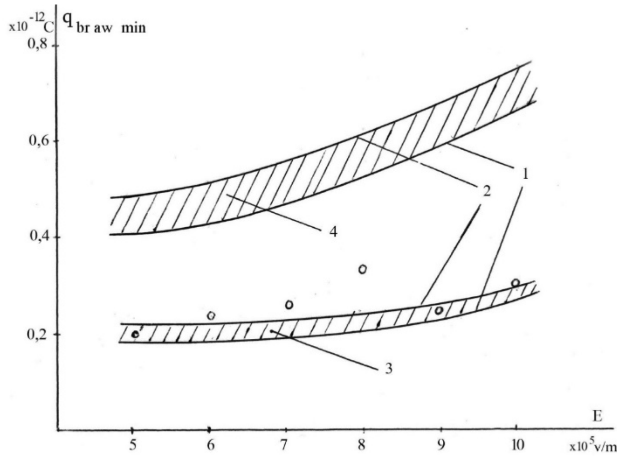

Fig. 2 Dependence of minimum charges of particles on the voltage of electric field

3-particle oriented along the least semiaxle

4-particle oriented along the largest semiaxle

Rutile a_{el} = 106 μm, b_{el} = 72μm, c_{el} = 54μm, $a_{eq\ sp}$ = 74μm, γ_p = 4,25·10^3 kg/m^3 ,

1-ε_1 = 31, 2-ε_2 =173

Considering that dielectric permeability of the rutile was unknown, calculation was carried out according to literary data.

Conclusion

In compliance with the obtained data, it is possible to conclude:

1. The minimum charge magnitude of the particles broken away from the electrode increases with the increase of the field strength
2. Breaking away from the charging electrode, particles with the minimum charge do not have time to change orientation and they break away from them with the semiaxle in the oriented position
3. Considering the experimental data of the minimum charge the adhesion force acting on the particle, as compared with the both gravity and electric forces, can be neglected.

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ანოტაცია. ბრტყელი კონდენსატორის ერთგვაროვან ელექტრულ ველში მიმდინარეობს მინერალური ნაწილაკების ინდუქციური დამუხტვის პროცესი. ნაწილაკებზე მოქმედ ძალთა ბალანსიდან უგულებელყოფილია ადჰეზიის ძალა და თეორიული გაანგარიშების საფუძველზე ნაწილაკების მიერ მიღებულია მინიმალური მუხტის ის მნიშვნელობა, რომელიც აკმაყოფილებს დამმუხტავი ელექტროდიდან მათი მოწყვეტის პირობას.

არასფერული ნაწილაკების ელექტროდზე ორიენტაციის ორი უკიდურესი შესაძლებლობა და მიღებული შედეგები შედარებულია ექსპერიმენტით მიღებულ მონაცემებთან.

საკვანძო სიტყვები: ადჰეზიის ძალა; დეპოლარიზაცია; ელექტროსეპარაცია; მინიმალური მუხტი; ნაწილაკების ორიენტაცია.

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Зависимость минимального заряда отрывающихся частиц от зарядного электрода модельного конденсатора электросепаратора от напряженности электрического поля

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Аннотация. В работе происходит индукционная зарядка минеральных частиц в однородном электрическом поле плоского конденсатора. Из баланса сил, действующих на частице, не учитывается сила адгезии и на основе теоретических расчетов получены те минимальные значения зарядов частиц, которые удовлетворяют условия их отрыва от зарядного электрода. При расчете учитываются два крайних положения: нахождение несферических частиц на зарядном электроде и полученные значения минимального заряда, отрывающего частиц от электрода, сопоставляются соответствующие их экспериментальным значениям.

Ключевые слова: деполяризация; минимальный заряд; ориентация частицы; сила адгезии; электросепарация.

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