INDUCTION MACHINES FOR ELECTRODYNAMIC SEPARATION OF NON-FERROUS METALS

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Abstract: The paper is devoted to the problems of research of induction machines for electrodynamic separation in the traveling magnetic field. Different designs of separators (with cylindrical or linear primary) are applied depending on capacity of units and on wastes properties.

Key words: induction machines, electrodynamic separation, characteristics, parameters.

1. Introduction

The development of environmental protection technology and creation of equipment for its realization are among the actual modern problems. Preliminary extraction of metallic particles from solid wastes is one of the obligatory conditions in the various technological processes of recycling solid wastes of manufacture and consumption. Electrodynamic separation is based on the force interaction of a magnetic field with eddy currents induced in conducting particles by a time changing field. This force literally ejects the conducting particle from the product stream. It is the most effective for the recovery of non-ferrous metals. For example, there are excellent separation results in a wide range of application [1-2]:

1. Separation of non magnetic metals from mixed solid waste stream (municipal or industrial);
2. Non magnetic metals induction sorting;
3. Recovery of materials from scrap wires and cables or electronic scrap;
4. Separation of conductive metals particles according to size;
5. Recovery of non-ferrous conductive metals from foundry mould sands;
6. Aluminium slag benefication.

The modes of electrodynamic separation may be divided into the following groups depending on the character of reasons stipulating induction of eddy currents in conducting particles:

a) Transition of particles in spatial non-uniform magnetic field;

b) Influence of a pulsing magnetic field of high frequency upon the conducting particles;

c) Influence of a travelling magnetic field created by three-phase winding of linear induction motor or by moving permanent magnets.

The different separators designs are available to adapt the systems to the material, whether coarse, medium or fine grain. The first two modes are characterized by rather small efficiency at large power consumption and require preliminary wastes preparation (chopping or crushing, sorting according to their dimension). The use of these modes of separation is effective for processing of wastes with the dimension of particles no more than 10 mm. Electrodynamic separators with travelling magnetic field do not require preliminary wastes preparation are easily built in existing technological lines and characterized by constructive simplicity and reliability. A suitable magnetic field configuration can be created by the stator of a linear induction motor or by moving permanent magnets (or electromagnet), over which conductive particles are forced to move. The examples of the most wide spread designs of one-sided separators with a travelling magnetic field are shown in fig. 1.

Due to these advantages such type of separators has found application for extraction of non-ferrous metals from municipal solid wastes, for processing automobile breakage, for extraction scrap from foundry sand, etc. [1-3].

Electrodynamic separators with a travelling magnetic field are similar to linear induction machines (LIM) with the short secondary. As it is known, operating of LIM is characterized by display of a series of specific effects: longitudinal end effects, transverse edge effects, ‘thickness’ effect - significant change of the field along the height of an air gap.

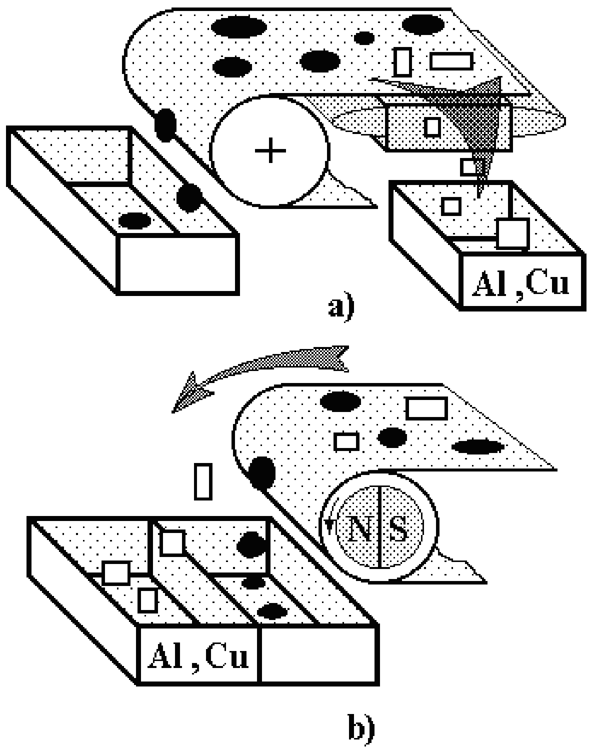

Fig. 1. Electrodynamic separators with linear induction machine (a) and with magnetic rotor (b)

The phenomena stipulated by variety of the form and small sizes of extracted particles (less then travelling magnetic field wave period) are added to the mentioned above. In addition, the physical properties of the medium and the competing force depend on the type waste. That is why for the problems solution in the first stage it is offered to consider only flat rectangular conducting plate with sizes *b*a*d* as the secondary of LIM separators model. The LIM primary are considered to be of infinite length (on axes *x* and *y*). The short secondary occupies the whole air gap between primary cores on length *b* and widths *a* in the model. The direction of travel of the secondary is *x* direction. Primary and secondary currents are uniformly distributed along the height of the air gap with density J_1 and J_2. Secondary current density has two components (on axes *x* and *y*), and a primary current density - one component (on axis *y*). Primary current density is represented by a complex function, which is defined by

$$J_1 = J_{1m} e^{-j\alpha x},$$

where $\alpha = \pi/\tau$, $\tau -$ pole pitch of primary.

In accordance with these assumptions the two-dimensional mathematic model of LIM with short secondary is offered [3]. For example, the following expression of the force operating on conducting plate is obtained:

$$F_x = -\mathrm{Re}\frac{\mu_o}{2}\delta\int_0^b\int_{-a/2}^{a/2}\dot{H}_{z2}\overset{*}{J}_{1m}\,dxdy =$$

$$= \frac{4}{\pi^2}\mu_o ab\delta\,\mathrm{Re}\left\{\sum_{n=1}^{\infty}\frac{1}{(2n-1)^2}\cdot\frac{\varepsilon_o s J_{1m}^{\;2}}{\alpha(1+\lambda_n^{\;2}/\alpha^2+j\varepsilon_o s)}\times\right.$$

$$\left.\times\left[1-k_{1n}\frac{1-e^{(\chi_{1n}+j\alpha)b}}{(\chi_{1n}+j\alpha)b}+k_{2n}\frac{1-e^{(\chi_{2n}+j\alpha)b}}{(\chi_{2n}+j\alpha)b}\right]\right\}, \quad (1)$$

where: $k_{1n} = \dfrac{e^{\chi_{2n}b}-e^{-j\alpha b}}{e^{\chi_{1n}b}-e^{\chi_{2n}b}}$,

$$k_{2n} = \frac{e^{\chi_{1n}b}-e^{-j\alpha b}}{e^{\chi_{1n}b}-e^{\chi_{2n}b}},$$

$$\chi_{1n} = \alpha\left[\frac{\varepsilon_o(1-s)}{2}+\sqrt{\frac{\varepsilon_o^{\;2}(1-s)^2}{4}+\left(\frac{\lambda_n}{\alpha}\right)^2+j\varepsilon_o}\right],$$

$$\chi_{2n} = \alpha\left[\frac{\varepsilon_o(1-s)}{2}-\sqrt{\frac{\varepsilon_o^{\;2}(1-s)^2}{4}+\left(\frac{\lambda_n}{\alpha}\right)^2+j\varepsilon_o}\right].$$

In (1): ε_o - goodness factor of LIM:

$$\varepsilon = \frac{2\mu_0\cdot\gamma\cdot f\cdot\tau^2\cdot\Delta}{\pi\cdot\delta_{ý}}. \quad (2)$$

Conclusion

The analysis of the results of researches shows, that the separating efficiency is greatly influenced by the conducting particles size (fig. 2), by the magnetic flux density value and the magnetic field frequency (fig. 3).

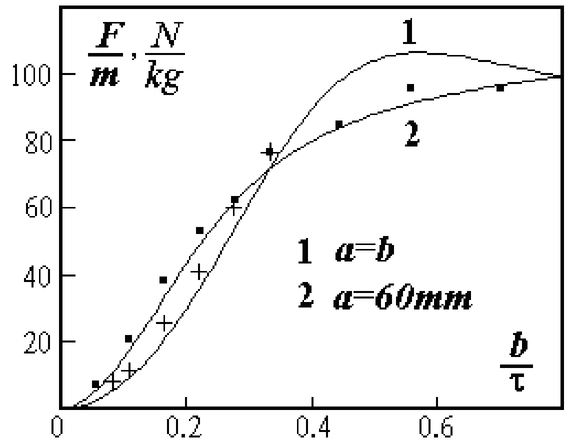

Fig. 2. Influence of the particles shape and size

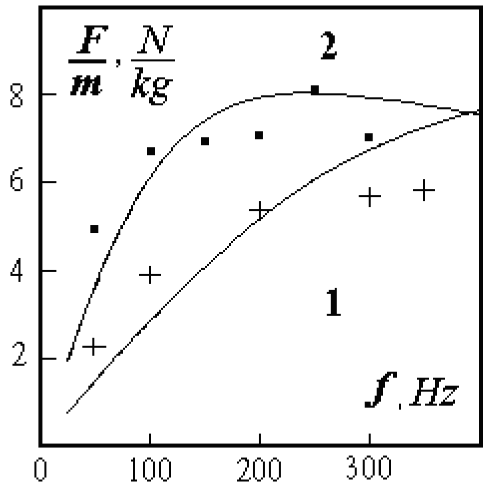

Fig. 3. Force vs. magnetic field frequency

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