Improving the Efficiency of NFe Metals Recovery from MSWI Bottom Ash

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Non-ferromagnetic (NFe) metals in bottom ash from waste-to-energy plants constitute a small fraction but its economic value is relatively high when compared with glass, ceramics, magnetic fraction and ferrous scrap. Any attempt to improve the efficiency of the ferrous and NFe scrap recovery should respect the fact that ferrous and NFe metals are present in the bottom ash in ranges of 7-15% and 1-2%, respectively (Sabbas *et al.*, 2003; Baun *et al.*, 2007).

Electromagnetic separation of NFe metal particles is usually performed in two steps. At first, ferromagnetic particles are removed by strong permanent magnets or electromagnets, and then NFe particles are separated from bottom ash fractions because of changed trajectories using eddy currents (EC), induced in the separated objects by changing magnetic field. Most commonly used eddy current separators (ECS) use a quickly rotating drum with a series of oppositely polarized strong magnets on its circumference. Dynamic effect of the separating force acting on conductive particles depends on many parameters especially the size, shape, specific weight and conductivity of the separated material, properties of other fractions including humidity and their mutual interaction, but also the type and arrangement of the ECS.

A general theory of EC-induced forces is rather complicated and therefore, a lot of attempts to solve suitable models have been performed (Dodd and Deed, 1968; Schlömann, 1975; Rem *et al.*, 1997; Zhang and Forssberg, 1997; Fähnrich *et al.*, 2017). The separating force is a consequence of interaction between the magnetic field and induced eddy currents (Lorentz force). In the approximation of small particles, it is given by multiplying the magnetic field gradient by the particle magnetic moment. The last vector quantity is in principle a dot product of the particle polarizability tensor and the magnetic induction, multiplied by the particle volume.

Not going to detail in this abstract, the main theoretical problem lies in determining the particle polarizability which has complicated frequency behaviour (see Fig. 1). It is convenient to introduce a dimensionless quantity $s = \omega\mu_0\sigma R_s^2$ comprising angular frequency ω, particle conductivity σ and its characteristic dimension R_s; μ_0 is permeability of vacuum. Depending on the particle shape, the reduced quantity has a critical (break) value s_B of the order of 10, determining two different regions of the particle behavior. As an example for aluminum sphere with 1 mm diameter the value $\omega_\mathrm{B} = s_\mathrm{B}/\mu_0\sigma R_s^2 = 1.256 \times 10^6$ rad/s (200 kHz).

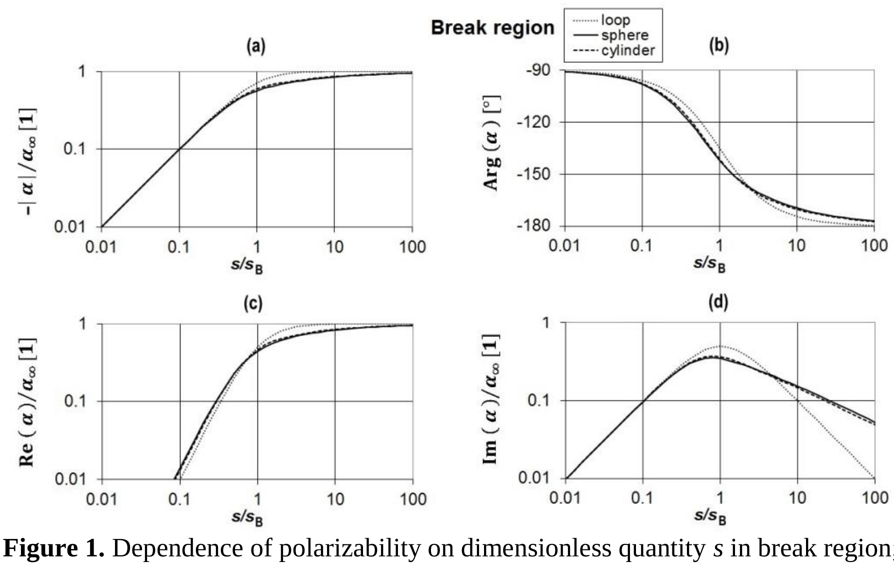

Figure 1. Dependence of polarizability on dimensionless quantity *s* in break region; (a) absolute value; (b) phase shift; (c) real part; (d) imaginary part.

In the case $\omega \ll \omega_\mathrm{B}$, the field inside the particle is predominantly due to the external field and eddy currents are too low to influence it – it corresponds to the case of negligible skin effect. In this region, polarizability components increase with frequency. On the contrary, under the condition $\omega \gg \omega_\mathrm{B}$, the strong skin effect is screening the external field in the near vicinity of the surface so that the field inside is zero. In short: ECS usually work near below the break region given for an average particle of the fraction under separation.

More thorough theoretical treatment can show the delicacy of the polarizability tensor dependence on the particle shape in coincidence with experiments (e.g. Zhang *et al.*, 1998). EC separation efficiency is higher for flat particles than for spherical ones of the same volume and material. Theory and experiment suggest that, when using ECS to recover NFe metals, the particles in the material stream should be as flat as possible.

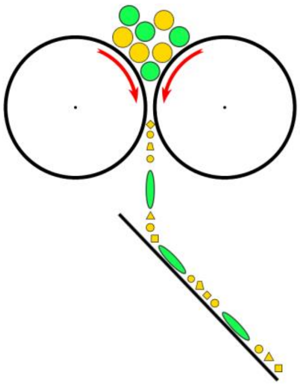

Figure 2. A schematic double drum crusher optimizing the shape of metal (green) particles

This finding brings us to a conclusion that the separability efficiency of NFe metal fraction in bottom ash from waste-to-energy plants could be raised by incorporating particle-shape changing equipment in front of the ECS. We propose to use a double drum crusher for small particles fraction that will press the malleable metal particles to flatter shapes but crush the fragile ones. As shown in Fig. 2, metal spheres will be pressed to rotational ellipsoids with better separation trajectories. Fig. 3 shows a proposed double drum crusher for a projected pilot plant.

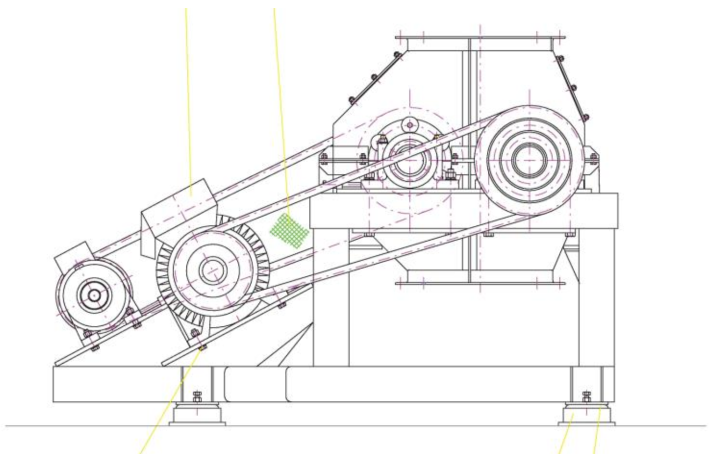

Figure 3. Drawing of a double drum crusher for the pilot plant

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