High Gradient Magnetic Separation for Powder Material Processing

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Abstract* – *High gradient magnetic separators are widely used in both research and industry. The aim of the work is the analysis of magnetic separation for powder material processing. The paper presents the simulations of magnetic field for magnetic separators with various filter shapes. Finite Element Analysis has been used to get the magnetic field over the studied separator grid.

Keywords – magnetic separation, material processing, high gradient magnetic separators, powder material, steel matrix.

I. Introduction

Most of the mineral separation techniques operate on the principle of differences in density and the use of heavy liquids, or differences in magnetic susceptibilities using Franz isodynamic magnetic separator. The mentioned methods are often time consuming and, in the case of heavy liquid application, potentially hazardous. Moreover, they are limited by the particle size of the materials to be separated; i.e. they work effectively with sand size fractions, but unproductive if applied to finer sand or clays. Though such small grains can be segregated with a high gradient magnetic separator (HGMS) [1]. The potential of HGMS has been recognized and applied to the beneficiation of many fine-grained industrial minerals, waste water treatment and are also relevant for protein isolation, cell separation, drug delivery, and biocatalysis [2].

II. Theory

In magnetic separator every particle experiences a net force that is an outcome of the competitive forces: magnetic force $\vec{F}_m$, drag force $\vec{F}_d$ and gravity force $\vec{F}_g$.

$$\vec{F}_m = \chi_m \mu_0 V_p (\vec{H}_0 \cdot \nabla)\vec{H}_0 \qquad (1)$$

$$\vec{F}_d = 6\pi\eta r(\vec{v}_f - \vec{v}_p), \qquad (2)$$

$$\vec{F}_g = (\rho_p - \rho_f) V_p \vec{g}, \qquad (3)$$

where χ_m is magnetic susceptibility, $\mu_0 = 4\pi \times 10^{-7}\ H/m$, V_p particle volume, $\vec{M}$ magnetization, $\vec{H}_0$ external magnetic field, η viscosity, r particle diameter, v_f fluid velocity, v_p particle velocity, ρ_p particle density, ρ_f fluid density and $\vec{g}$ gravitational acceleration.

If magnetic force exceeds fluid drag and gravity force particles of different magnetic susceptibilities become separated. As (1) indicates magnetic force is nonzero only in the presence of magnetic field gradients that in a HGMS device are produced at the sharp edges of magnetic stainless steel matrix. The magnetic forces due to these gradients are capable of trapping even micron-size particles of very weekly magnetic minerals from a slurry fed through the steel matrix.

III.HGMS application to clay-size particle separation

The greatest number of publications on the HGMS application concern to the application to clay-size particle (kaolin beneficiation and water purification). Nevertheless, considering the ratio of magnetic and other forces HGMS can be effective over particle sizes ranging from about one micron to about one millimeter in diameter [3]. The experiments involving HGMS are conducted with materials in the coarse silt to fine sand size range (30 – 250 microns). In the experiments of the particle separation, that sizes are of a few tens microns the problems of the magnetic matrix blockage have been reported [4]. The retention of the non-magnetic fraction at the matrix can be due mechanical trapping, presence of polymineralic grains or actual magnetic capture of nonmagnetic fracture [4]. The relative importance of these mechanisms with respect to the samples and conditions have been not yet examined. Though, the experiments on the stainless powder separation that particle diameters were 10 to 100 micron have shown the cohesive forces as the reason for the separation efficiency drop [5]. In dry magnetic separation of powder state the cohesive force between particles is strong compared with that in the wet type of separation. If the diameter of object for separation becomes smaller the cohesive forces increases because specific surface of particle becomes larger and consequently the magnetic force to the object becomes smaller. As the result of this mechanism the magnetic separation gets problematic. In order to make the separation efficiency higher the optimization of magnetic field configuration by numerical analysis can be performed. The examples of magnetic mesh filter arrangement and mesh filter have been shown in Fig. 1. Filter units are usually made of ferromagnetic stainless steel.

The result of magnetic field analysis of various filter arrangement are shown in Fig 2. Magnetic field generated around the filter wires of different cross section geometry has been calculated. In the model the magnetic field of 2T in the flow direction was applied. The filter wires have dimensions of 1 mm and the two-dimensional grid spacing is 10 mm.

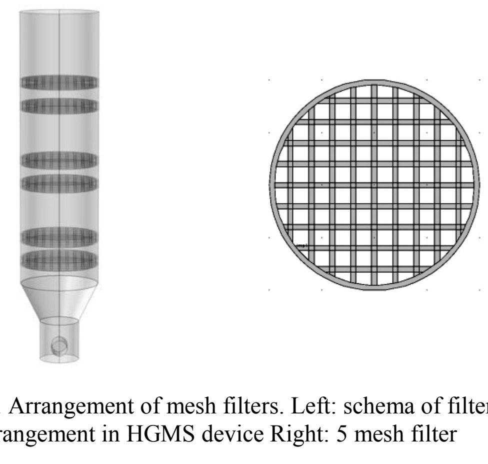

Fig. 1. Arrangement of mesh filters. Left: schema of filter arrangement in HGMS device Right: 5 mesh filter

The calculations show different field distribution for various filter cross sections. The magnetic fields are lower on the left and right sides of the wires that causes that the relatively smaller forces are there produced. The separated powder come through the filter and is accumulated on the upper and lower sides. Powder is not accumulated on the left and right sides and the blockage is prevented that has been proved by the experiments [6].

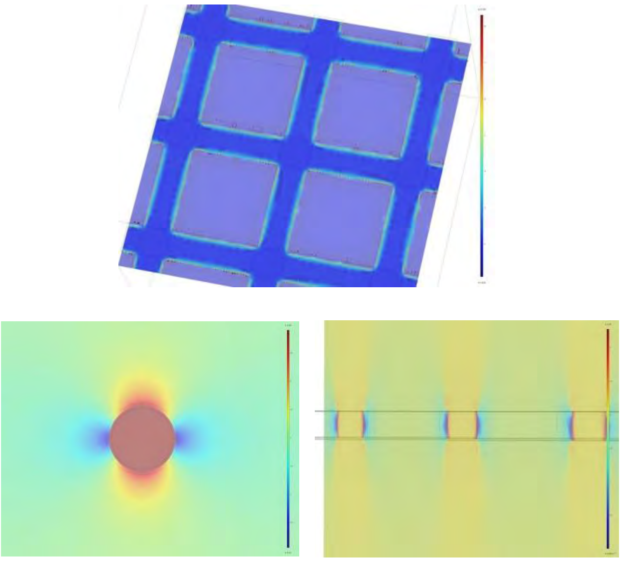

Fig. 2 Top: magnetic field distribution over a HGMS mesh filter. Bottom left and right: magnetic flux density norm around circular and square shaped filter

Conclusion

In dry type of high gradient magnetic separation some problems of material blockage are common that is caused by particle coagulation or deposition. Fine particles are aggregated each other by the cohesion between them. To solve the problem optimization of separator filter can be done. The performed simulations have shown that shape of the filter plays an important role in preventing the blockage. Changing the shape of the filter varies the distribution of magnetic field strength and gradient and therefore magnetic force becomes more significant on the top and bottom of the filter. Thus, the accumulation of the particles between the wires is avoided and the separation efficiency gets higher. The next step is an experiment with HGMS employing various filter arrangements.

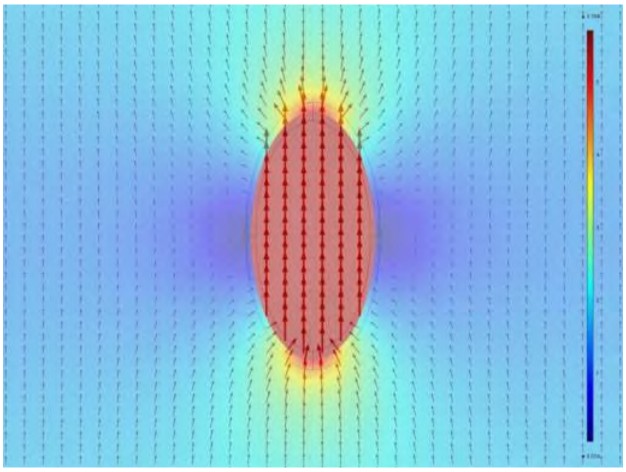

Fig. 3. Magnetic flux density norm around oval shaped filter wire. Arrows show the direction of magnetic field

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