



Quantitative investigation on magnetic capture of single wires in pulsating HGMS

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ABSTRACT

Pulsating high gradient magnetic separation (HGMS) achieves high separation efficiency to fine weakly magnetic minerals with a rod matrix. In practice, the matrix is made of numerous cylindrical wires, so that an insight into the magnetic capture of single wires to magnetic minerals would provide a crucial foundation for the analysis, design and choice of matrix. In the investigation, the magnetic capture of single wires to ilmenite minerals and its dependence on the key parameters of a pilot-scale pulsating HGMS separator, i.e., magnetic induction, pulsating frequency and feed velocity, is investigated using an innovatively experimental method. It is found that these parameters have significant effects on the magnetic capture of single wires; the mass weight of magnetic particles captured onto the wires increases with increase in magnetic induction, and it is opposite for pulsating frequency and feed velocity. The cylindrical wire captures more particles than that of rectangular one, due to its larger capture area, and it has a stronger adaptability to variations in the parameters. The single wire captures more magnetic particles but a greatly reduced stability to the parameters' variation, compared to the multi-wires. This experimental method provides a new perspective in the understanding of magnetic capture to magnetic particles in a HGMS process, contributing to the optimal design of matrix and to the improvement of HGMS performance.

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1. Introduction

The performance of high gradient magnetic separation (HGMS) in the past three decades is dramatically enhanced in the field of mineral processing, allowing it to play a key role in the concentration of weakly magnetic minerals from metallic ores and in the removal of such minerals from non-metallic ores. This accomplishment is essentially resulted from the technical breakthrough in pulsating HGMS, which addressed the long-term problem of matrix clogging as encountered in conventional HGMS methods [1]. As can be seen from Fig. 1, pulsating HGMS is achieved by a slurry exposed to pulsation in the separating zone of a vertical separating ring carrying rod matrices in the full-scale pulsating HGMS separators [2]. In the past two decades, the applications of this method have been accelerating in the world, with the maximum processing capacity reaching around 1000 t/h at an electricity power consumption dramatically reduced to 0.27 kW per ton of ore, in the largest SLon-5000 full-scale pulsating HGMS separator developed in 2014.

It should be noted that the use of rod matrix as shown in Fig. 1 has significantly facilitated the popularized installations of the pulsating HGMS separators, due to its reliable operation and simple combination; this popularity is also resulted from its resistance to mechanical clogging as the slurry flows freely in the matrix [3]. In a pulsating

HGMS separator, the matrix plays a carrier for the capture of magnetic particles, thus its configuration produces a decisive control on the pulsating HGMS performance [4]. In practice, the matrix is made of numerous cylindrical wires, so that an insight into the magnetic capture of single wires to magnetic particles would provide a crucial foundation for the analysis, design and choice of the matrix. In fact, over the decades many people have investigated the capture of a single wire to magnetic particles in high gradient magnetic field; these works include observing the capture behaviors of single wire through high-speed imaging [5], analyzing the capture dynamics of single wire to magnetic particles [6, 7], matching the size ratio between magnetic wire and particle [8], and optimizing the matrix configuration to enhance HGMS performance using COMSOL Multiphysics, SMA method, etc. [9–11]. It also deserves attention that in the recent years, there is emerging discussions whether irregularly-shaped wires such as helical [12] and elliptic [13] ones have superior magnetic field characteristics to the rod matrix as applied in pulsating HGMS and thus present greater application potentials.

These investigations and discussions are encouraging, as they provide a potential possibility for improving the HGMS performance. But, it is also interesting to note that these works are basically restricted in the theoretical and simulative descriptions on the magnetic capture of single wires to magnetic particles [15], and until today they are not well established with valid data due to the insufficient method available to confirm such works. In this investigation, the magnetic capture of

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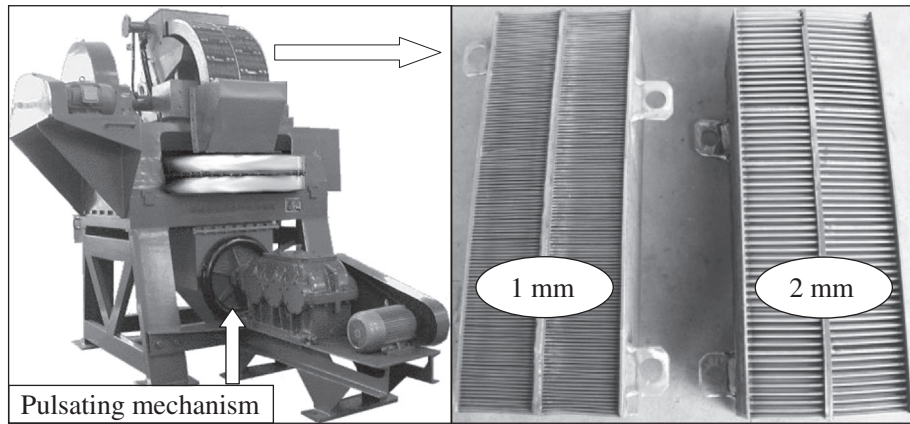


Fig. 1. SLon full-scale pulsating HGMS separator [14] and rod matrices [2].

single wires to fine ilmenite minerals and its dependence on the key parameters of a pilot-scale pulsating HGMS separator, i.e., magnetic induction, pulsating frequency and slurry velocity, is investigated using an experimental Magnetic Capture Analysis method; moreover, this method is used to compare the magnetic capture of single wires with that of multi-wires.

2. Brief description on pulsating HGMS process

2.1. Cyclic pilot-scale pulsating HGMS separator

A cyclic pilot-scale pulsating HGMS separator is used for the investigation. As can be seen from Fig. 2, a pulsating mechanism is installed below the magnetic yoke of the separator. When the separator is

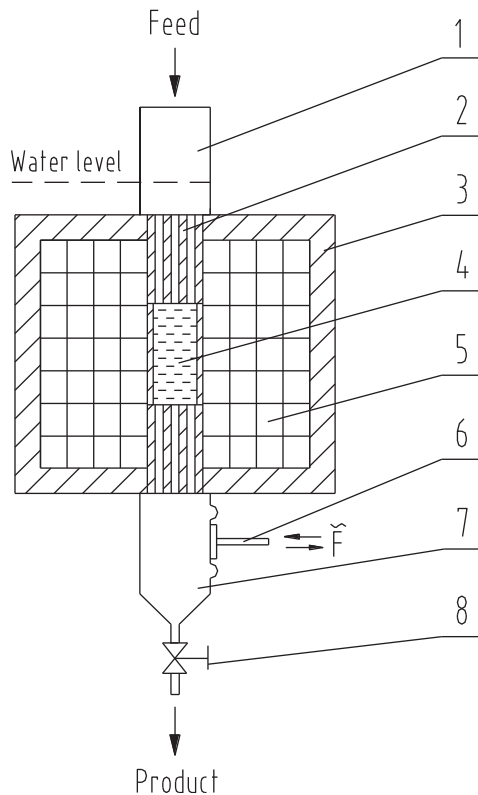


Fig. 2. Cyclic pilot-scale pulsating HGMS separator [1]: 1 = feed box, 2 = magnetic pole, 3 = magnetic yoke, 4 = magnetic matrix, 5 = energizing coils, 6 = pulsating mechanism, 7 = product box, 8 = valve.

operated, a direct current flows through the energizing coils and a magnetic field is built up in the separating zone of the separator. Firstly, the separating zone is filled with flowing water so that the pulsating energy is transmitted to the separating zone, in which the level of water and its flowrate is adjustable through the valve below the pulsating mechanism. Then, the slurry is fed into the matrix located in the separating zone via feed box. Magnetic particles are attracted from slurry onto the matrix, while non-magnetic particles pass through the matrix and go out of the product box to become a non-magnetic product, under the combined actions of slurry pulsation, hydrodynamic drag and gravity. The pulsating mechanism drives the slurry in the separating zone up and down, keeping particles in the matrix in a loose state so that magnetic particles can be more easily captured by the matrix and non-magnetic particles can be more easily dragged out of the matrix.

This separator is fed periodically. When a batch of feed is finished, the energizing current is switched off and the magnetic particles captured onto the matrix are washed out to get a magnetic product. A more detailed description on the pulsating HGMS is reported [2].

2.2. Theoretical description on magnetic capture of a single wire

As shown in Fig. 3, suppose a cylindrical magnetic wire of radius a is placed in the separation zone of the pilot-scale pulsating HGMS separator and a uniform magnetic field B_0 is applied in the separating zone. A

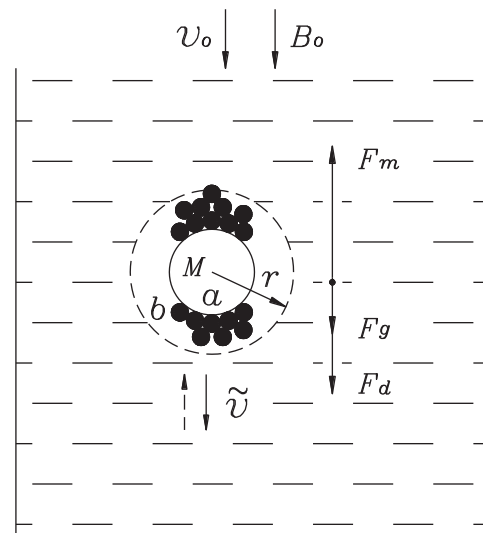


Fig. 3. Magnetic capture of a single cylindrical wire to magnetic particles in a pulsating HGMS process.

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