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Capture Characteristics of Combinative Rod Matrix in High Gradient Magnetic Separation

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Abstract

The single diameter rod matrix is now widely applied for high gradient magnetic separation (HGMS) of weakly magnetic ores, due to its resistance to clogging, simple combinatorial optimization and high operational reliability. The capture characteristics of a combinative rod matrix, which consists of different diameter rod elements, were investigated during the pulsating HGMS of ilmenite concentrate. The results indicate that the combinative matrix was able to achieve simultaneous magnetic capture improvement to fine and coarse ilmenite particles under the suitable operating conditions, compared with the single diameter rod matrices. The magnetic induction and pulsating frequency of the pulsating HGMS process have their effects on the capture performance of the combinative matrix. The capture performance of the combinative matrix improves with increase in the magnetic induction, particularly for -21μm fine ilmenites, but this improvement will be destroyed under the excessively high pulsating frequency. It was concluded that the combinative rod matrix has provided a potential candidate for improving the current HGMS performances.

Keywords: High gradient magnetic separation; Combinative rod matrix; Capture characteristics; Ilmenite

Introduction

High gradient magnetic separation (HGMS) is a key technology for the effective separation of weakly magnetic ores [1]. In practice, it is now widely used for separating weakly magnetic iron oxide, ilmenite, wolframite and manganese ores, etc., and for purifying quartz, feldspar, kaolin and other non-metallic ores [2]. In the HGMS process, a high magnetic field gradient is produced on the surface of magnetic matrix in a uniform magnetic field, to achieve the required magnetic capture force to weakly magnetic minerals from fluid [3]. In the process, the size of magnetic elements in the matrix has a remarkable influence on the HGMS performance [4]. It has been widely acknowledged that, in the actual HGMS process a fine matrix is mostly used for separating fine magnetic particles, while a coarse matrix is suitable for separating coarse magnetic particles. For example, when a pulsating HGMS separator was applied to concentrate hematite or ilmenite in the range from 0.037 to 0.074mm in the mineral processing industry, the 2.0mm diameter magnetic matrix has been most suitably applied and achieves the best separation performance. But for the finer hematites below 0.02mm, the 1.0mm diameter magnetic matrix surpasses the 2.0mm one [5], and this phenomenon is like that of ilmenites [6]. However, in the industrial practice, most of the materials to be processed by HGMS method are distributed in wide particle sizes. Therefore, it is imaginable that the use of a combinative rod matrix consisting of both fine and coarse rod elements may be more applicable for the HGMS of weakly magnetic ores with wide particle size distributions.

Recently, Chen et al. have methodically studied the influence of diameter, arrangement, spacing and layer of rod elements on the pulsating HGMS performance using Slice Matrix Analysis method. In this method, a matrix is manufactured to consist of several different slice matrices [7-9], so that the internal and microscopic investigation to the magnetic capture of matrix for a HGMS process is achievable. Using this method, Ding et al. found that the 2/3mm combinative rod matrix improves the concentrate grade of pulsating HGMS for hematite tailings, while the 3/2mm one improves the iron recovery, compared with the 2- and 3-mm single diameter rod matrices. In fact, the improvement of HGMS performance using a combinative matrix was also reported in a patent proposed by Panzhihua Mining Group in China [10]. These previous studies have shown the effectiveness of combinative matrix. However, there are few reports on the capture characteristics of a combinative rod matrix while used for separations. In this work, a combinative rod matrix was used to investigate its capture characteristics for capturing ilmenite particles in the pulsating HGMS process.

Experimental

Description of sample

An ilmenite concentrate assaying 45.34% TiO2 was used for the capture investigation. The detailed particle size distribution of this concentrate is characterized by BT-9300S Laser Particle Size Distribution Analyzer, as shown in Table 1. 61.59% of the material is less than 44.4 μm and 40.37% is less than 21.0μm. These fractions are rich in titanium, accounting for 61.62% and 40.40% of the total titanium value, respectively.

Table 1: Particle size Distribution of Sample.

Size range (μm)	-21	+21.0-44.4	+44.4-75.8	+75.8-104.4	+104.4-143.9 143.9	+143.99	Totalal
Mass weight (%)	40.37	21.22	20.36	12.66	4.97	0.42	100
Grade (% TiO_2)	45.38	45.33	45.31	45.3	45.26	45.42	45.34
Distribution (% TiO_2)	40.4	21.22	20.35	12.65	4.96	0.42	100

Methods

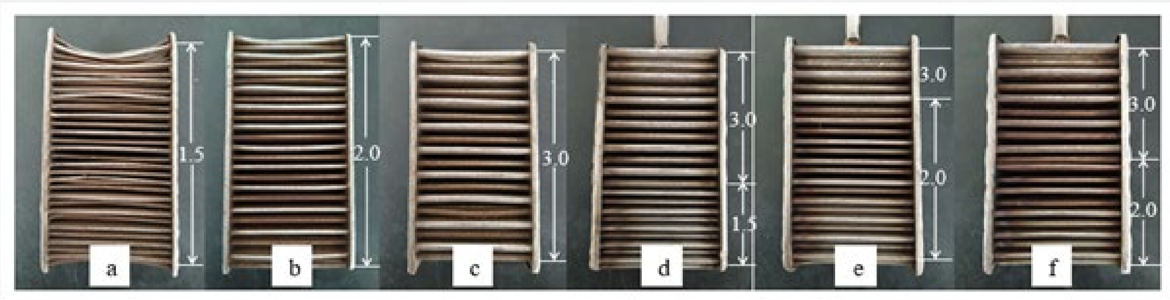

Figure 1: Single diameter and combinative rod matrices.
(a)1.5 mm single diameter rod matrix
(b) 2.0 mm single diameter rod matrix
(c) 3.0mm single diameter rod matrix
(d) 3.0/1.5 mm combinative rod matrix of 2:1 height ratio
(e) 3.0/2.0mm combinative rod matrix of 1:2 height ratio
(f) 3.0/2.0mm combinative rod matrix of 1:1 height ratio

The present investigation was carried out through a SLon-100 cyclic pulsating HGMS separator made in SLon Magnetic Separator Ltd. Before experiments, the operating conditions of the separator were determined through optimizing tests with a 2.0 mm single diameter rod matrix. The optimum conditions were determined at pulsating stroke of 6 mm, feed solid concentration around 10% and feed volume flow rate around 10 L/min, and the sample was excessively fed to the separator at a mass weight of 350g to achieve a saturation capture of the magnetic wires in matrix. Magnetic induction and pulsating frequency of the separator were adjusted in the ranges from 0 to 1.2 T and 0 to 260 r/min, respectively. The single diameter and combinative rod matrices shown in Figure 1 were comparatively used on the pulsating HGMS separator for separations, under the same conditions such as magnetic induction and feed velocity. It is noted that the height ratio of combinative rod matrix is defined as the height ratio of different diameter rod elements. When a batch of feed was finished in the separator, the ilmenite particles captured onto the matrix was dried, weighted and analyzed by BT-9300S Laser Particle Size Distribution Analyzer.

Results and Discussion

Capture performance of single diameter and combinative rod matrices

Controlling the magnetic induction and pulsating frequency of the SLon-100 cyclic pulsating HGMS separator at 0.8T and 180 r/min respectively, the capture characteristics of single diameter and combinative rod matrices were comparatively investigated. From Figure 2, the saturated capture weight of ilmenite particles on the single diameter matrices increases with increase in the diameter of rod elements as the coarser element has a larger capture surface compared with that of finer element. The 1.5mm single diameter matrix produced an apparently higher weight for -21μm fine ilmenites and a slightly lower weight for +21μm coarse ilmenites, compared with the 2.0mm and 3.0mm single diameter matrices. This is in accordance with the early investigation of pulsating HGMS for fine hematite [11], i.e., a fine matrix tends to capture fine magnetic particles and a coarse matrix tends to capture coarse ones.

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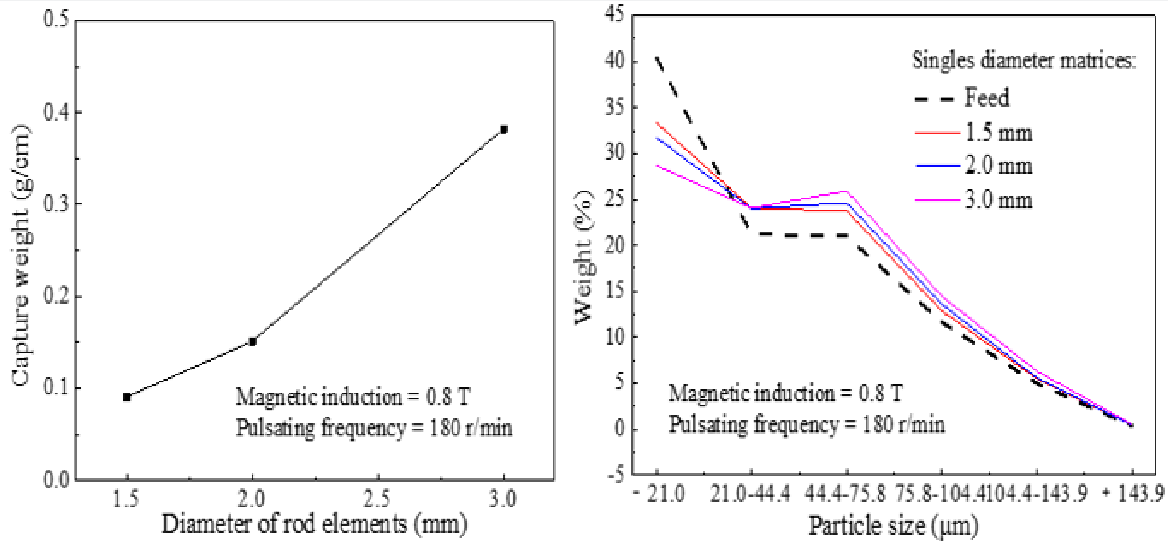

Figure 2: Capture performance of 1.5mm, 2.0mm and 3.0mm single Diameter Matrices.

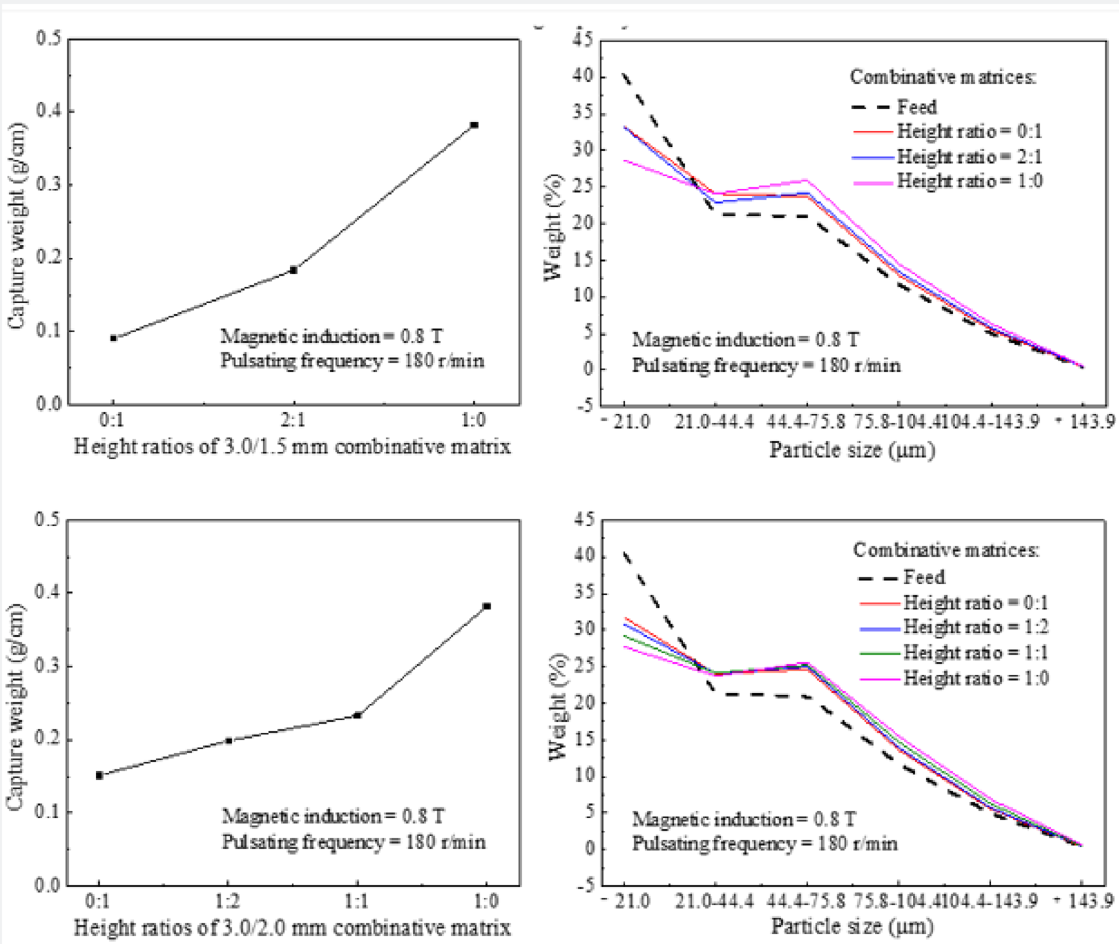

Figure 3: Capture performances of 3.0/1.5mm (up) and 3.0/2.0mm (down) Combinative Matrices.

However, as shown in Figure 3, when the 3.0mm and 2.0mm or 3.0mm and 1.5mm rod elements were respectively combined into 3.0/2.0mm or 3.0/1.5mm combinative rod matrices at certain height ratios, they did not strictly produce capture

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weights according to their height ratios in the matrix; instead, they produced smaller capture weights compared with the single diameter matrices. For instance, under the same conditions, the capture weights of 3.0mm and 1.5mm single diameter matrices were around 0.4g/cm and 0.1g/cm respectively, and thus the capture weight of the 3.0/1.5 mm combinative rod matrix with 2:1 height ratio should be around 0.3 g/cm; but, as we can see in Figure 3, its actual capture weight is less than 0.2 g/cm. On the other hand, the capture ability of fine rod elements to fine ilmenites was obviously reflected in the combinative rod matrices. It can be seen in Figure 3, when 1.5mm or 2.0mm rod elements were combined with 3.0 mm rod elements, the weights for -21μm fraction were significantly improved; and, the smaller is the height ratio of 3.0/2.0mm in the combinative rod matrix, the higher is the weight for the -21μm fraction. It is also interesting to note that the capture performance of combinative rod matrix to coarse ilmenites were well kept, so that the combinative matrix was able to achieve simultaneous magnetic capture improvement to fine and coarse ilmenite particles.

Effect of magnetic induction

Controlling the pulsating frequency of the SLon-100 separator at 180 r/min, the effect of magnetic induction on the capture performance of a given 3.0/1.5mm combinative matrix was further investigated, with results shown in Figure 4. It seems that the 0.8 T and 1.2 T high magnetic inductions do not produce significant effects on the capture weight in this combinative matrix; however, the low magnetic induction of 0.4T does. For the three magnetic inductions, the capture weight increased with increase in the height ratio and in the magnetic induction. It was found that under the low magnetic induction of 0.4T, the particle size distribution was almost the same when the height ratio of combinative matrix was increased from 0:1 to 2:1 and to 1:0. But, as the magnetic induction was improved to 0.8T and 1.2T, the combinative matrix significantly improved its capture ability to the -21μm fine ilmenites, as clearly shown in Figure 4. Therefore, under the high magnetic induction condition the combinative matrix could achieve an improved simultaneous magnetic capture to fine and coarse ilmenite particles.

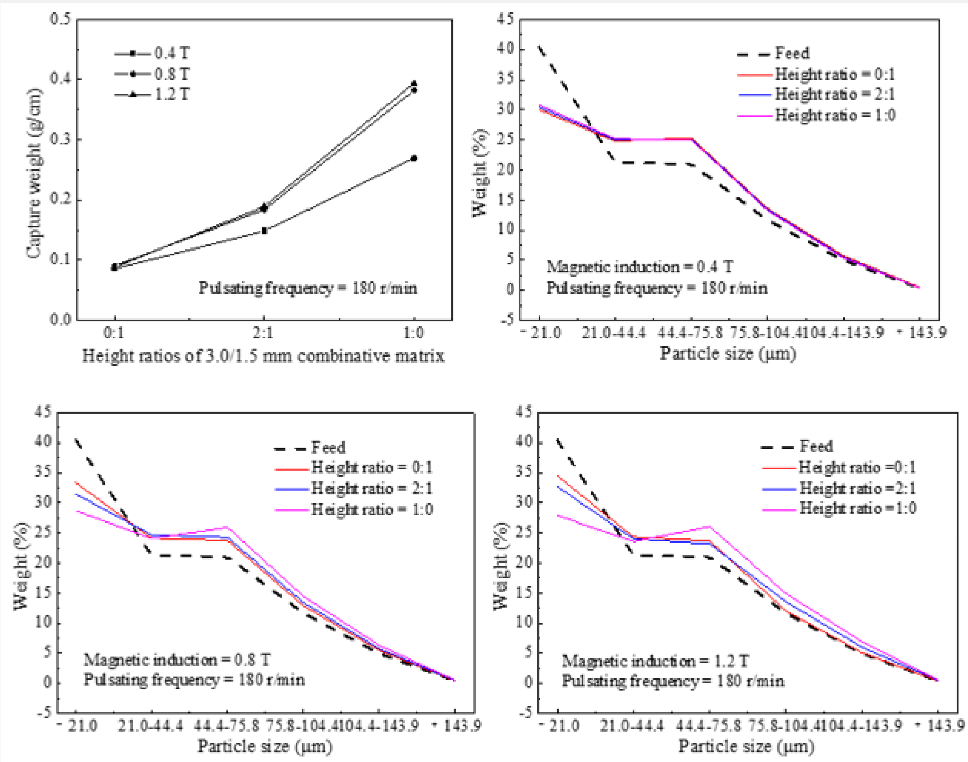

Figure 4: Effect of Magnetic Induction on Capture performance of 3.0/1.5mm Combinative Matrix

Effect of pulsating frequency

The pulsating frequency, another key operational parameter of SLon-100 separator, was also changed to investigate its effect on the capture performance of the 3.0/1.5 combinative matrix, and this investigation was performed at the high magnetic induction of 0.8T. As shown in Figure 4, the capture weight gently decreased with increase in the pulsating frequency from 160r/min to 220r/min. However, the increased frequency produced a very negative effect on the magnetic capture to -45μm ilmenite particles, for all the height ratios in the combinative matrices. And under the highest pulsating frequency of 260r/min, the affected ilmenite particles enlarged from -45μm to -105μm.

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Therefore, the improved magnetic capture to fine magnetic particles in the combinative rod matrix will be destroyed by the excessively strong pulsating condition, which is the same as that in the single diameter rod matrix (Figure 5).

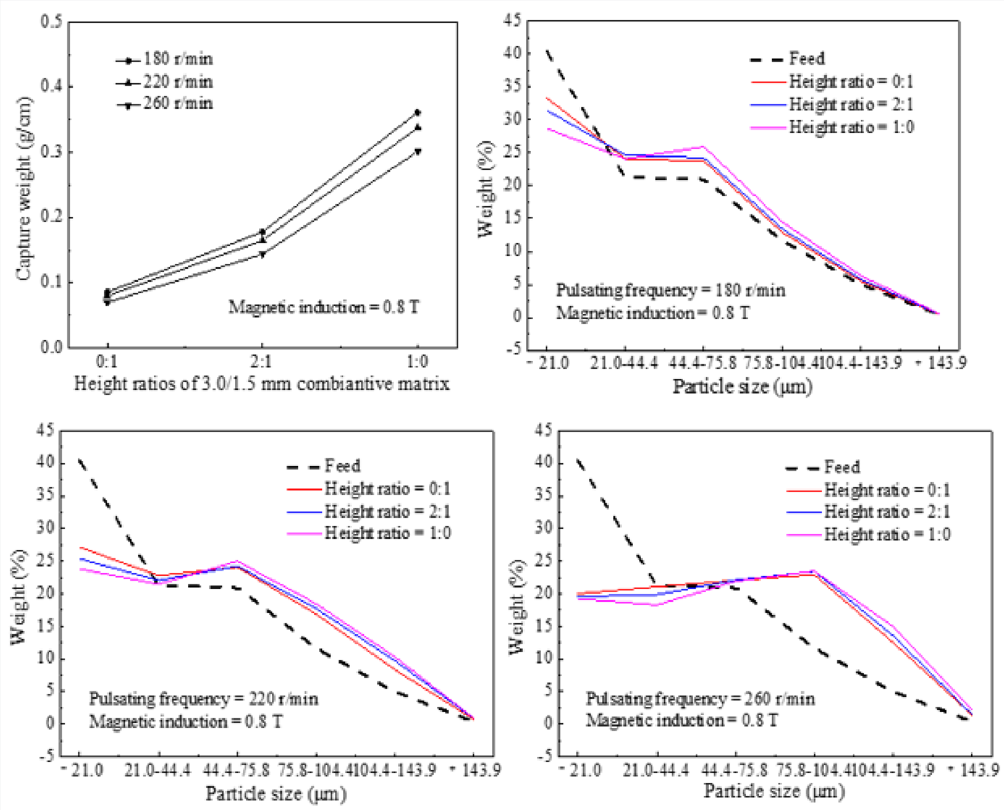

Figure 5: Effect of Pulsating Frequency on Capture performance of 3.0/1.5mm Combinative Matrix.

Conclusion

The following two conclusions can be drawn from the results and discussion above:

a) The combinative rod matrix does not strictly capture magnetic particles according to the height ratios of different single diameter rod elements in the matrix; instead, they produced smaller capture weights compared with the single diameter matrices.

b) The combinative rod matrix achieves simultaneous magnetic capture improvement to fine and coarse ilmenite particles, under the suitable operating conditions such as magnetic induction and pulsating frequency in the pulsating HGMS process. But, this improved capture performance in the combinative rod matrix could be destroyed under the excessively strong pulsating condition, as we know in the pulsating HGMS of single diameter rod matrix.

It was concluded that the combinative rod matrix would provide a potential candidate for improving the current HGMS performances.

Acknowledgment

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