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A wet belt permanent high gradient magnetic separator for purification of non-metallic ores

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ABSTRACT

A wet belt permanent high gradient magnetic separator (referred here as WBHGMS) was developed on the principle of HGMS in an inclined slurry flow of several centimeters thick. In this investigation, a pilot-scale WBHGMS separator was introduced and used to purify a quartz ore, to study the effect of key variables such as belt rotation speed and belt inclination angle on the separation performance. The results of investigation indicate that changes in the rotation speed and inclination angle as well as the rinsing water consumption have significant influences on the performance, and an increase in these variables increases the Fe_2O_3 grade but decreases the iron removal rate of non-magnetic product. When they are respectively optimized at 5 r/min, 5° and 8.3 L/min, it produced a non-magnetic product assaying 0.0166% Fe_2O_3 at an iron removal rate of 43.97% (nearly 95% for magnetic minerals) from the ore assaying 0.0359% Fe_2O_3; such a separation performance correlates well with the industrial operation of full-scale WBHGMS separators in purifying the ore. This pilot-scale separator also produced a non-magnetic product assaying 0.041% Fe_2O_3 at an iron removal rate of 58.70% (nearly 96% for magnetic minerals) from a feldspar ore assaying 0.068% Fe_2O_3. It was concluded that this HGMS separator has provided an effective method for the removal of magnetic impurities from non-metallic ores.

1. Introduction

The presence of colored impurities such as iron and titanium oxides reduces the whiteness and transparency of a large amount of non-metallic ores such as quartz, feldspar and kaolin, and thus degrades their commercial values (Chen et al., 2012). For instance, when the quartz sand is used as raw material for the manufacture of glass in China, a Fe_2O_3 content lower than 0.02% with particle size ranging from 20 to 140 mesh (0.11–0.83 mm) is usually required; and the lower the iron content, the greater its application areas (Banza et al., 2006). Iron oxides in these ores are typically presented as discrete particles or surface coatings even as inclusions in target minerals, and they are mainly distributed in the forms of magnetite, hematite, limonite and iron silicates. In addition, the interfusion of fine iron scraps produced during the crushing and grinding processes of the ores could not be ignored.

Physical and chemical methods such as magnetic and gravity separations (Bleifuss and Hopstock, 2001), flotation and various leachings may be used to remove these impurities from non-metallic ores (Štyriaková et al., 2006); but in practice, magnetic separation presents an economically-efficient way in the removal of magnetic elements from such ores, due to its simple operation, renewability and environmental friendliness. The flotation and leaching methods are more expensive and environmentally hazardous (Štyriaková et al., 2007), though they are able to achieve a higher iron removal. In fact, there is an increasing practice to combine magnetic and flotation or leaching methods, to meet the low-cost operation and environmental restrictions while a complicated non-metallic ore is intended to be processed (Hu et al., 2012; Santos et al., 2015). In the combined method, magnetic separation is preferred to remove magnetic impurities, followed by flotation or leaching method to remove non-magnetic impurities from the ore.

Pulsating high gradient magnetic separation (HGMS) is now applied to remove magnetic minerals from non-metallic ores (Chen and Li, 2013). However, when it is used for the processing of these ores, the prior removal for strongly magnetic minerals such as magnetite as well as fine iron scraps is usually demanded to avoid matrix clogging. Although drum magnetic separators are practically applied to beneficiate magnetic ores, they cannot be effectively used to remove a small quantity of strongly magnetic minerals and fine iron scraps from non-metallic ores, as the magnetic force in these separators is not sufficient to reach into the deep slurry flow and capture the fine magnetic particles from the slurry.

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For this purpose, a wet belt permanent high gradient magnetic separator (WBHGMS) was developed on the principle of HGMS in an inclined slurry flow; and in recent years, it is successfully applied for purification of non-metallic ores such as quartz, feldspar and garnet. In this investigation, a pilot-scale WBHGMS separator was introduced and used to purify a quartz ore, to study the effect of key variables such as belt rotation speed and belt inclination angle on the separation performance of the separator. Moreover, its performance in purifying a feldspar ore and the application of full-scale WBHGMS separators in purifying the quartz ore are briefly introduced in the investigation.

2. Experimental

2.1. WBHGMS separator and its working procedure

A PBC-0210 (magnet width × length = 200 × 1000 mm) pilot-scale WBHGMS separator was used in the investigation. As shown in Fig.1, it mainly consists of a wearable belt and its tensioning mechanism, a plate-type magnet and its inclination angle adjusting mechanism, motor, driving roll and product launders.

The belt is 1.5–2.0 mm thick and is uniquely made into a shallow U-shaped chute with raised edges on both sidewalls, wherein slurry flows downward. Perpendicular to the belt rotation, bulged strips are arranged on the belt surface at a given interval, to retain the magnetic particles captured onto the belt by magnetic poles beneath the belt. As illustrated in Fig.1, the magnet is made into a long plate with NdFeB blocks; these blocks are assembled with polarities aligned in the belt rotation and alternately aligned across the belt width, using a unique method to overcome the enormous magnetic force between the blocks (Chen et al., 2016). Narrow magnetic poles are arranged between NdFeB rows to produce high magnetic field and field gradient, so that a strong magnetic force is achievable on the belt surface to capture fine magnetic particles from slurry. With such a design, the poles act as a magnetic matrix, and thus this WBHGMS is labeled as a high gradient magnetic separator.

When the separator is operated, the slurry enters through feed box onto the U-shaped belt, and flows downward at a uniform thickness of several centimeters. Magnetic particles in the flow are captured onto the belt and carried upward by the bulged strips. When they are carried to the rinsing area under the rinsing water trough, magnetic deposits are fully scattered due to the direct impinging of rinsing water onto the deposits, and entrained non-magnetic particles are rinsed out of the deposits. Then, magnetic particles are further carried to the corner of belt, where they are flushed into the magnetic product launder by water sprays. Non-magnetic particles flow downward with the slurry to become a non-magnetic product.

The main technical parameters of this pilot-scale separator are specified in Table 1.

It is derivable that in a WBHGMS process, the required magnetic force for capture of a magnetic particle on the belt surface is related to the property of particles such as permeability and density, the operating parameters of belt such as rotation speed and inclination angle, and the characteristics of slurry such as flow velocity on the belt.

2.2. Description of samples

The quartz ore used for the investigation was obtained from a quartz processing plant in Hubei province of China. It has a controlled particle size distribution from 0.13 to 0.85 mm, with its detailed size analysis and chemical composition listed in Tables 2 and 3, respectively. The ore essays 0.0359% Fe_2O_3, and its iron phase analysis indicates that iron elements in the ore are distributed in magnetite, hematite and limonite (in total 46.38%) as well as in iron silicate minerals (53.62%,

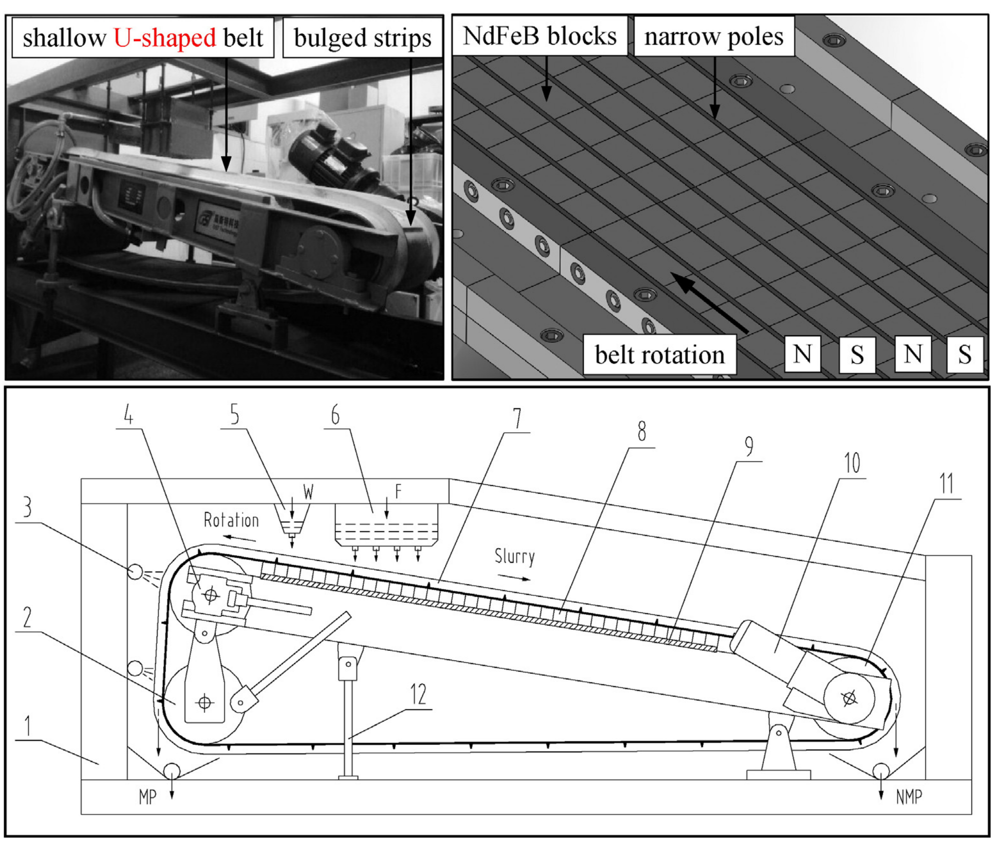

Fig. 1. Pilot-scale WBHGMS separator (top left), plate-type magnet (top right) and schematic diagram of separator (below): 1 = support frame, 2 = driven wheel, 3 = water sprays for magnetic particles, 4 = tensioning mechanism for belt, 5 = rinsing water trough, 6 = feed box, 7 = belt (with bulged strips), 8 = permanent magnet, 9 = steel backing plate, 10 = motor, 11 = driving roll, 12 = inclination angle adjusting mechanism for magnet. W = rinsing water, F = feed, NMP = non-magnetic product, MP = magnetic product.