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Study on iron removal by S-HGMS from tungsten tailings

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Abstract

Comprehensive utilization of tungsten tailings resources not only solves environmental problems but also creates huge economic benefits. The high content of iron impurity in tungsten tailings will have adverse effect on the downstream comprehensive utilization, whether flotation or pickling. In this paper, the Superconducting High Gradient Magnetic Separation(S-HGMS) is used to remove of Fe impurities from tungsten tailings. The optimal experimental parameters are as follows: background magnetic induction intensity is 3.0T, slurry flow velocity is 500ml/min. The Fe removal rate of Fe was 68.8% and the recovery rate was 59.53%.

Keywords: tungsten tailings, removal of Fe, S-HGMS, slurry flow velocity

1. INTRODUCTION

With the development of urbanization, more and more tailings are created. Tailing refers to the residual material extracted from useful components through a series of processes such as crushing, grinding and sorting during the development and utilization of mineral resources [1]. As the large scale mining, and backward mineral processing technology, China has produced a large number of tailings. According to incomplete statistics, at present, China's domestic tailings storage has exceeded 15 billion tons, becoming the largest output and the largest pile of solid waste in China [2]. Tungsten tailings have long been ignored by people. These pollutants not only pollute the surrounding environment, such as soil, water and air, but also cause social problems, harm to animals and plants, and even people's health [3].

Magnetic separation is a vital beneficiation method commonly used in the separation and concentration processes of magnetite such as chromite [4-5]. The first application of superconducting HGMS in mineral processing field was to improve the whiteness of kaolin clay by eliminating iron impurities, which achieved good test indices [6]. The permanent magnet generate the magnetic field only in the area near its surface, when the slurry flows through this small area in a large flow rate, leading to a decrease in separation efficiency. However, superconducting high gradient magnetic separation technology is a simple, efficient, cheap, pollution-free, nondestructive and efficient iron-bearing material separation and enrichment technology [7].

The purpose of this study is to reduce the iron content in the tungsten tailings as much as possible, so as to reduce the burden of extracting high-purity SiO_2 from the tungsten tailings in the next step, such as flotation and acid leaching. The research group has successfully extracted glass raw materials from gold tailings that meet the Chinese secondary standards [8]. Therefore, we explore the experimental parameters of high gradient magnetic separation, analyze and discuss some influencing factors and theoretical basis.

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2. MATERIALS AND METHODS

2.1. Materials

The raw material of the experiment is waste tungsten tailings from a certain area of China. Samples came from different parts of the mine. Samples were collected and mixed to a cloor of yellowish white. The mixed samples were analyzed for particle size. The result is shown in Fig 1. From Fig.1, it is clear that d (0.9) =160.431μm, d (0.5) =32.863μm and d (0.1) =3.524μm. Among them d (0.9) =160.431μm means 90% of the pulp particles are below 160.43um. The particle size distribution of tungsten tailings is uneven and the particle size is rather fine. Although the content of ore particles below 200 mesh is 73.58%, in order to improve the utilization efficiency of tungsten tailings, simple ore grinding treatment is needed. The gringded tailings are screened with a 200 mesh screen. XRF test was carried out on the samples after screening, and the analysis results of the main chemical components of the tested tailings were shown in Table 1. The content less than 0.05% were not marked.

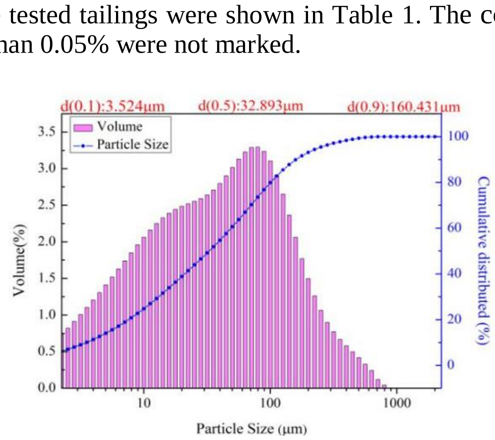

Fig.1. Grain size distribution curve.

TABLE 1
ANALYSIS RESULTS OF MAIN CHEMICAL COMPOSITION OF TUNGSTEN TAILINGS (XRF).

Component	SiO_2	Al_2O_3	K_2O	Fe_2O_3	CaO	MgO	Na_2O	TiO_2	MnO	WO_3	CuO	F
Content/%	66.18	14.63	4.30	6.38	3.12	1.96	0.42	0.46	0.26	0.23	0.16	1.15

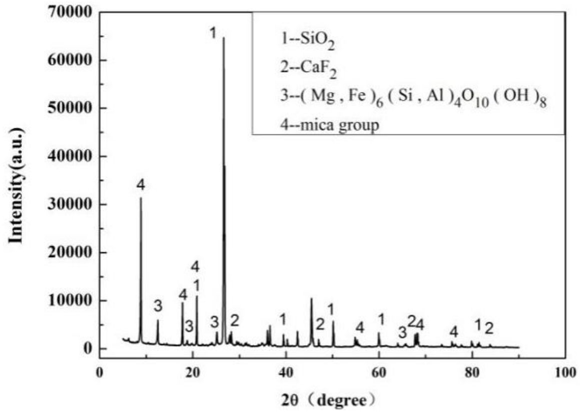

Fig. 2. XRD analysis of tungsten tailings.

According to Table 1, the content of SiO_2 is 66.18%. Our ultimate goal is to produce high purity silica from tungsten tailings. However, the contents of Fe, Al and Mg were high, which brought great difficulties to the next step whether it is flotation or acid leaching. In order to further determination of the mineral composition of tungsten tailings, XRD analysis of tungsten tailings was carried out. XRD analysis results are shown in Fig.2.

It can be seen from Table.1 of XRF chemical composition analysis and Fig.2 of tungsten XRD results that the main minerals are quartz, fluorite and mica, and iron is mainly rich in chlorite. According to the mineral susceptibility manual, the specific magnetization coefficient of chlorite varies between (12.24～46.19)×$10^{-9}$$m^3$/kg, while that of fluorite varies between (0.14～1.54)×$10^{-9}$$m^3$/kg and that of quartz between (0.90～0.24)×$10^{-9}$$m^3$/kg. Mica group minerals are mainly white mica, almost diamagnetic. This provides a theoretical feasibility for removal of iron by high gradient magnetic separation. Thus, the downstream burden of comprehensive utilization of quartz and fluorite is reduced.

2.2. Experimental system

The superconducting high gradient magnetic separator adopted in the experiment was independently designed by institute of high energy physics, Chinese Academy of Sciences. The intensity and direction of the magnetic field varies at each position inside the magnet bore, where a non-uniform magnetic field is generated by the high gradient superconducting magnet, so the degree of non-uniformity of the magnetic field is expressed by the magnetic field gradient, namely gradH. The direction of magnetic field gradient is the direction of the maximum change rate at this point, and the magnetic field intensity is the maximum value of the change rate. Grinded tungsten tailings are mixed into slurry with different concentration in the experiment. Under the condition of continuous agitation, the slurry is sucked into the separator by drive pump at different flow rates for magnetic separation. Adding some steel wool in the reactor not only could increase the magnetic field gradient, but also the wool could be used as a carrier to adsorb magnetic ore particles. The separation schematic diagram is shown in Fig.3. Finally, the material adsorbed by steel wool and the material in water are studied after drying.

The particles with stronger magnetism will stick tightly to the steel wool, while the particles with weaker magnetism will flow out with the water.

3. RESULTS AND DISCUSSION

3.1. Dependence of magnetic field strength

In superconducting high gradient magnetic separation, magnetic force greater than competitive force is a necessary and sufficient condition for separation, magnetic particles are magnetized in the magnetic field and the magnetic force is:

$$F_M = \mu_0 k_0 H_0 gradH_0$$

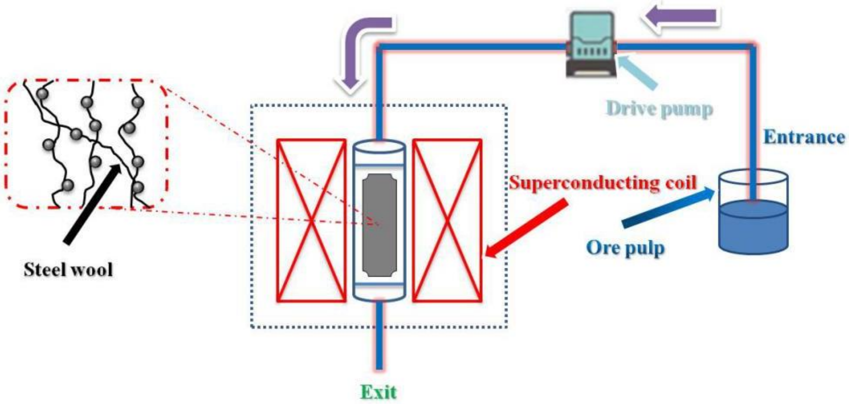

Fig. 3. Shematic diagram of superconducting magnetic separation.

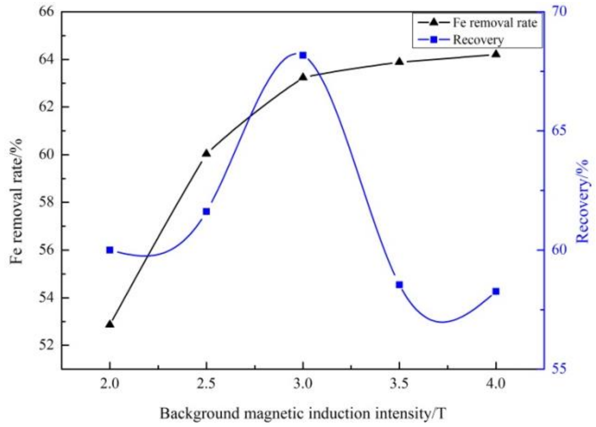

Fig. 4. Effect of background magnetic induction intensity on Fe removal rate and recovery.

Among them:

μ_0 ---permeability of the material of magnetized particle

k_0---volume size of the magnetized particles

H_0---field strength

$gradH_0$---the magnetic field gradient

It can be clearly seen that the background magnetic induction intensity has a significant effect on the improvement of magnetic force, so as to overcome the competitive force and realize the adsorption of magnetic particles in the slurry. To study the influence of the magnetic induction intensity, we selected preliminary parameters including 15 g/L as the pulp density, 400 ml/min slurry flow speed controled by a peristaltic pump, 8% steel wool filling ratio, we did the experiment at several magnetic induction intensity value which are 2.0 T, 2.5 T, 3.0 T, 3.5 T, 4.0 T respectively, and repeated the experiment for three times, the result is shown in Fig. 4.

Fe removal ratio refers to the portion of Fe adsorbed by steel wool. Recovery is the proportion of the sample in water. Fe removal ratio and recovery ratio changes according to the variation of the magnetic induction intensity, in the figure Fig.4, it shows that as the magnetic induction intensity increasing, the removal ratio of Fe rises all the way, when the magnetic induction intensity is 4.0 T, the removal ratio reached 64.21%. But when the magnetic induction intensity increasing, the recovery ratio slowly rising at first, and then decreasing afterwards when the magnetic field is higher than 3.0 T, this is due to the strong magnetic induction intensity makes the weak magnetic particles gathered on the steel wool, too much accumulation of particles caused the decreasing of the recovery. Therefore, we chose 3.0T as the best background magnetic induction intensity. At this time, the Fe removal rate reached 63.24% and the recovery rate reached 68.17%.

Figure 5 is the XRD contrast diagram of steel wool samples and water samples under the condition of 3.0T. It can be seen that the peak value of chlorite decreased, while the peak value of SiO_2 increased slightly. This proves the effectiveness of superconducting magnetic separation technology.

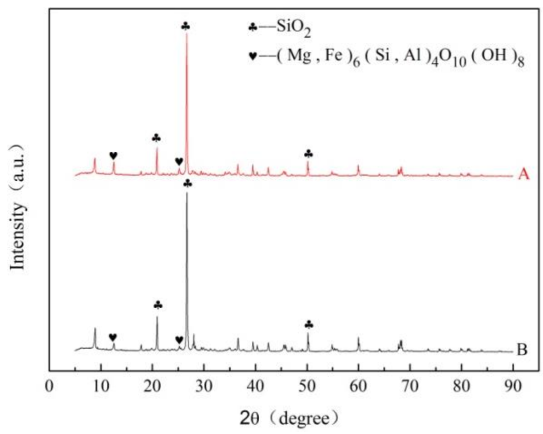

Fig. 5. XRD contrast figure,A: Steel wool adsorption sample, B: The water samples.

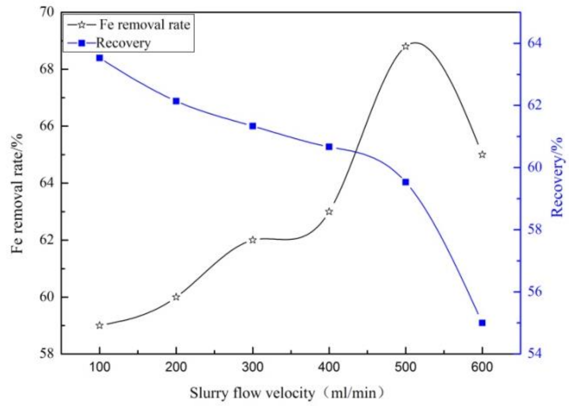

Fig. 6. Effect of slurry velocity on Fe removal rate and recovery rate.

3.2. Effect of slurry velocity on experiment

As can be seen above, background magnetic induction intensity is an important factor affecting high gradient magnetic separation. In the mineral processing, the competitive force is mainly concentrated on the viscous force of pulp. For fine particles, the viscous force in pulp is:

$$F_D = 6\pi\eta r v_0$$

Type in the:

η--- Dynamic viscosity coefficient of pulp;

v_0--- Pulp flow velocity

It can be seen that the viscous force of pulp is mainly related to the flow rate which could be controlled manually. In the experimental process of exploring the influence of slurry velocity, the background magnetic induction intensity is 3.0T, and the pulp concentration is 15g/L, the filling rate of steel wool is 8%, and the speed of slurry flow is realized by controlling the speed of peristaltic pump. The slurry flow rate of continuously stirred pulp was set as 100, 200, 300, 400, 500 and 600ml/min, and three tests were conducted. The steel wool adsorbed sample and the sample in water were precipitated, dried and finally tested for its composition. The result is shown in figure 6. At the beginning, the removal rate of Fe gradually increased, and there are some non-magnetic ore particles mixed in the magnetic ore particles, due to the scouring effect of the flowing slurry, it causes those adsorbed non-magnetic ore particles leaving from the surface of the steel wool. However, with the increase of the slurry velocity, some of the ore particles adsorbed on the outer layer of the steel wool were washed away by the slurry, so that some magnetic ore particles could not adsorb on the steel wool, resulting in the decrease of removal rate. It can be seen that the optimal value is obtained at the slurry flow rate of 500ml/min. The removal ratio of Fe was 68.8%, the recovery ratio was 59.53%.

4. CONCLUSIONS

The S-HGMS technology is an effective way to remove iron from tungsten tailings as proved by a series of experiments. Based on mineral susceptibility, chlorite rich in iron in weak magnetic minerals can be effectively removed, and the grade of quartz and fluorite in diamagnetic materials can be improved.

In this paper, two important parameters in magnetic separation process are analyzed and discussed by single factor experiment: background magnetic induction intensity and slurry flow velocity. Under the background magnetic induction intensity of 3.0T and slurry flow velocity of 500ml/min, the iron removal rate of tungsten tailings reached 68.6% and the recovery reached 59.53%, which reduced the burden for downstream processes such as flotation and acid leaching. Because the high gradient magnetic separation combined with superconducting technology is physical separation, it can save energy and reduce the environmental pollution of the whole process.

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