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Loose-stratification model in separation process for vanadium pre-concentration from stone coal

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Abstract: A technology of one-stage roughing and one-stage scavenging vanadium pre-concentration with shaking table was investigated for improving vanadium grade and decreasing acid consumption minerals content based on the quantitative evaluation of minerals by scanning electronic microscopy (QEMSCAN). In order to visually illustrate how the vanadium-bearing minerals were separated from system, a loose-stratification model was established with Bagnold shear loose theory and Kelly stratification hypothesis. Through the model, it was inferred that fine fraction and coarse fraction of vanadium-bearing muscovite particles easily became the concentrate in roughing and scavenging stages, respectively. The type of the dominant effect on the loose-stratification was confirmed. In the roughing stage, gravity sedimentation played a leading role in the loose-stratification process. However, in the scavenging stage, shearing dispersion pressure caused by asymmetric motion of table deck took an important part in the loose-stratification process. Finally, the correction of the loose-stratification model was validated by the practical experiment.

Key words: loose-stratification model; pre-concentration; stone coal; separation process

1 Introduction

In China, vanadium is mainly recovered from vanadium−titanium magnetite ore and stone coal. The gross reserve of vanadium in terms of V_2O_5 in stone coal is 118 million tons which is 6.7 times that in vanadium−titanium magnetite, accounting for more than 87% of the domestic reserve of vanadium [1]. Therefore, many techniques of vanadium extraction from stone coal are researched and developed, and the techniques generally include roasting, acid leaching, ion purification, precipitation and calcinations [2−5]. However, owing to the low grade of vanadium and high content of acid consumption materials, the vanadium extraction techniques are always perplexed with the problems of enormous ore handling quantity, high energy consumption and high acid consumption [6,7]. Hence, the vanadium pre-concentration research for improving the grade of vanadium extraction raw material is necessary.

The vanadium pre-concentration from stone coal by beneficiation has been seldom investigated. WU et al [8] ever attempted to adopt the flotation method to pre-concentrate the vanadium. However, due to the carbonaceous mudstone covering on the surfaces of mineral particles, the floatability difference among mineral particles obviously decreased. The flotation separation result was not satisfactory. Shaking table is a kind of gravity separation method which is characteristic of high concentration ratio and not influenced by carbonaceous mudstone [9], hence the vanadium pre-concentration from stone coal by shaking table is taken into account. The vanadium pre-concentration flowsheet, technical indicators and economic benefit were firstly briefly introduced in this work. However, the loose-stratification behavior of mineral particles in the separation process of vanadium pre-concentration is still unclear and the dominant effect on the loose-stratification is also uncertain. Hence, the loose-stratification model in separation process was established with help of Bagnold shear loose theory [10] and Kelly stratification hypothesis [11]. Meanwhile, the type of the dominant effect on the loose-stratification was confirmed. The loose-stratification model can visually illustrate how vanadium-bearing minerals were separated from the system and the confirmed dominant effect type can provide theoretical guidance for optimization of

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technical parameters, such as lateral gradient, stroke and frequency of stroke. Finally, the loose-stratification model was validated by the practical experiment.

2 Experimental

2.1 Materials preparation

The stone coal was collected from Teng-da Mining and Metallurgy Co. Ltd., Hubei, China. Around 200 kg of representative ores were crushed to below 2 mm, with two-stage jaw crusher and one-stage roll crusher. The crushed samples were then uniformly mixed and divided into 100 portions. The mass of each portion was 2 kg. The divided samples were decarbonized in a SXZ-10-B muffle furnace at 700 °C for 60 min, and then the decarbonized samples were wet-ground for 6 min in a HLXMB−240×300 laboratory rod mill at 50% solids, until the particle size distribution of 63% below 74 μm was achieved. The ground products were the roughing feed for the shaking table.

2.2 Materials characterization

The chemical composition analysis and mineral composition analysis of the roughing feed were carried out by quantitative evaluation of minerals scanning electronic microscopy (QEMSCAN). Fix carbon (FC) content analysis was conducted with HTGF−3000 coal industry analyzer. The available element of the feed was only vanadium, and the main components were SiO_2 and Al_2O_3 (Table 1). From Table 2, it is shown that the main acid consumption minerals in the roughing feed are hematite and calcite. The previous research discovered that the most vanadium of the roughing feed existed in muscovite as isomorphism [12], and QEMSCAN studies reveal that most of muscovite are distributed in coarse particles and fine particles. The middle size particles have little muscovite (Fig. 1). The size distribution curve of the roughing feed is presented in Fig. 2. The mass

Table 1 Chemical composition of roughing feed for shaking table (mass fraction, %)

V_2O_5	SiO_2	Al_2O_3	Fe_2O_3	K_2O
0.82	54.36	10.59	5.93	4.90
Na_2O	CaO	MgO	S	FC
0.35	7.35	3.13	1.90	2.73

Table 2 Mineral composition of roughing feed for shaking table (mass fraction, %)

Quartz	Calcite	Muscovite	Feldspar	Hematite
35	12	13	13	11
Kaolinite	Silicate	Sulfate	Else	
5	4	4	2	

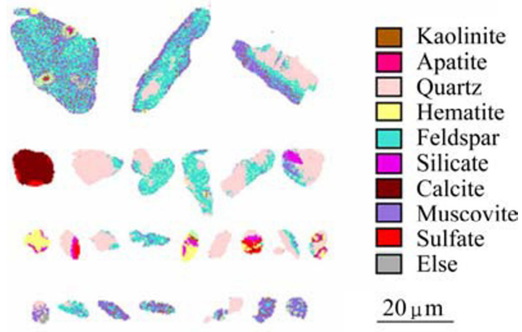

Fig. 1 Vanadium contribution particles in roughing feed for shaking table

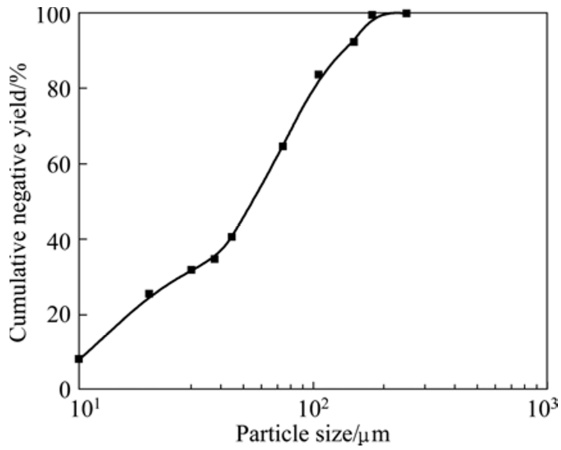

Fig. 2 Particle size distribution of roughing feed for shaking table

median diameter d_{50} and the density of the roughing feed are 54 μm and 2.72×10^3 kg/m^3, respectively.

2.3 Procedure and product measurement

The samples were treated by one-stage roughing and one-stage scavenging with RK/LY−1100×500 frequency conversion shaking table and the operation parameters were confirmed by condition experiments. The parameters of roughing were capacity of 30 kg/h, pulp density of 20%, lateral gradient (α) of 0.65°, horizontal flush water of 400 L/h, stroke of 16 mm and stroke frequency of 350 min^{-1}. The parameters in the scavenging stage were capacity of 20 kg/h, pulp density of 15%, lateral gradient of 0.90°, horizontal flush water of 300 L/h, stroke (l) of 16 mm and stroke frequency (n) of 350 min^{-1}. In the roughing stage, the separation products, from light mineral terminal to heavy mineral terminal, are called concentrate I, middling I and tailing I, respectively, and in the scavenging stage they are called concentrate II and final tailing, respectively.

The vanadium grade was determined in accordance with the Test Methods of Vanadium in Coal Standard [13]. The chemical analysis of products was performed