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Influence of Mechanical Activation on Acid Leaching Dephosphorization of High-phosphorus Iron Ore Concentrates

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Abstract: High pressure roll grinding (HPRG) and ball milling were compared to investigate the influence of mechanical activation on the acid leaching dephosphorization of a high-phosphorus iron ore concentrate, which was manufactured through magnetizing roasting-magnetic separation of high-phosphorus oolitic iron ores. The results indicated that when high-phosphorus iron ore concentrates containing 54.92 mass% iron and 0.76 mass% phosphorus were directly processed through acid leaching, iron ore concentrates containing 55.74 mass% iron and 0.33 mass% phosphorus with an iron recovery of 84.64% and dephosphorization of 63.79% were obtained. When high-phosphorus iron ore concentrates activated by ball milling were processed by acid leaching, iron ore concentrates containing 56.03 mass% iron and 0.21 mass% phosphorus with an iron recovery of 85.65% and dephosphorization of 77.49% were obtained. Meanwhile, when high-phosphorus iron ore concentrates activated by HPRG were processed by acid leaching, iron ore concentrates containing 58.02 mass% iron and 0.10 mass% phosphorus were obtained, with the iron recovery reaching 88.42% and the dephosphorization rate reaching 88.99%. Mechanistic studies demonstrated that ball milling can reduce the particle size, demonstrating a prominent reunion phenomenon. In contrast, HPRG pretreatment contributes to the formation of more cracks within the particles and selective dissociation of iron and P bearing minerals, which can provide the favorable kinetic conditions to accelerate the solid-liquid reaction rate. As such, the crystal structure is destroyed and the surface energy of mineral particles is strengthened by mechanical activation, further strengthening the dephosphorization.

Key words: high-phosphorus iron ore concentrate; high pressure roll grinding; ball milling; selective dissociation; sulfuric acid leaching; dephosphorization; iron recovery

High-phosphorus oolitic iron ore reserves are abundant in China, accounting for 14.86% (nearly 8 billion tons) of the country's total iron ore reserves. The average iron grade of these reserves is approximately 45%, which is much higher than the average iron ore grade of 32.6% in China[1]. However, high-phosphorus oolitic iron ores in China have not been widely used effectively. One of the major reasons is that the granularity of hematite in high-phosphorus oolitic iron ores is extremely fine and its embedded relationship with gangue minerals such as apatite is complex. Hence, it is very difficult to achieve effective dephosphorization via physical or chemical beneficiation processes[2,3]. With the rapid growth of the iron and steel industries in China, supplies of high-quality iron ores are becoming exceedingly limited. Therefore, dephosphorization of high-phosphorus oolitic iron ores is becoming an important but challenging issue.

At present, dephosphorization is realized mainly by beneficiation method[4], chemical method[5,6], microbial method[7] and pyrometallurgical method[8-11], etc. The conventional beneficiation method is usually featured by low dephosphorization rate, great loss of iron resources in residues and high production cost. In addition, the biological leaching method is now facing with serious problems such as low productivity, as well as difficulties in development of microbial cultures and industrialized production. The pyrometallurgical method, namely the removal of phosphorus from hot metal, usually leads to low dephosphorization rate, poor operating environment and a lot

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of heat loss. In contrast, the acid leaching method shows a great potential as it is applicable to more raw materials, and has higher dephosphorization rate and iron recovery rate. Nevertheless, its current development is restricted by some problems such as high acid consumption, environmental pollution and large production investment.

Currently, mechanical activation methods based on high pressure roll grinding (HPRG) or ball milling pretreatments attract significant attention, facilitating their successful application in the metallurgy[12,13], materials[14], and chemical[15] industries. Therefore, these methods can be used as alternatives to improve the chemical activity of high-phosphorus iron ore concentrates and strengthen dephosphorization, owing to reduced acid consumption and environmental pollution during acid leaching. Herein, HPRG and ball milling were used to separately pretreat high-phosphorus iron ore concentrates to investigate the influences of different mechanical activation methods on acid leaching dephosphorization. Furthermore, the strengthening mechanism of mechanical activation was determined.

1 Raw Materials and Experimental Method

1.1 Raw materials

The high-phosphorus oolitic hematite comes from the Exi region in China. Its initial iron grade is 41.50% and its phosphorus content is 1.24 mass%. After beneficiation by the magnetizing roasting-magnetic separation process, high-phosphorus iron ore concentrates were manufactured. Chemical composition and particle size distribution of the high-phosphorus iron ore concentrates are listed in Tables 1 and 2, respectively.

As shown in Table 1, the iron grade and phosphorus content of the high-phosphorus iron ore concentrates are 54.92 mass% and 0.76 mass%, respectively. Mineralogical studies show that the main mineral compositions are magnetite, quartz, fayalite and apatite. Nearly 94.76% of phosphorus in the high-phosphorus iron ore concentrates exists in the form of apatite (Fig. 1), which generally has a close embedded relationship with iron oxide minerals and the structure of pisolitic layered ooids (Fig. 2). Typically, the thickness of the apatite layer is 1−10 μm. Another form of phosphorus is found in the iron ore mineral by physical or chemical absorption, or crystalline substitution[16], and its content reaches nearly 3.31% total phosphorus content. Consequently, the majority of phosphorus cannot be removed via physical separation methods.

Table 1 Chemical composition of high-phosphorus iron ore concentrates mass%

TFe	Fe_2O_3	FeO	Al_2O_3	SiO_2	P	S	CaO	MgO	LOI
54.92	43.22	31.76	6.20	11.40	0.76	0.048	2.32	0.97	−2.22

Note: LOI—Loss on ignition.

Table 2 Size distribution of high-phosphorus iron ore concentrates

Particle size/mm	+0.150	0.076−0.150	0.038−0.076	−0.038
Content/mass%	31.50	35.05	20.70	12.75

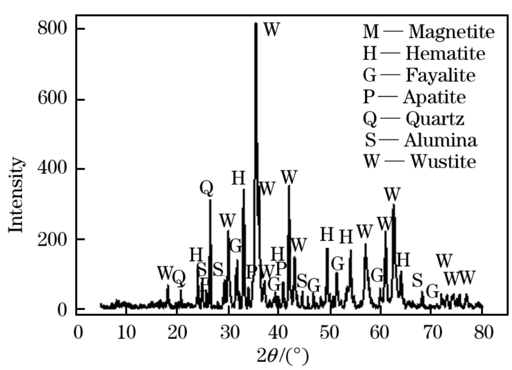

Fig. 1 X-ray diffraction pattern of high-phosphorus iron ore concentrate

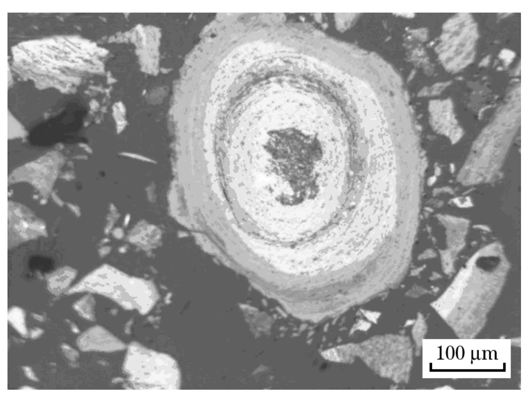

Fig. 2 Microstructure of high-phosphorus iron ore concentrates

1.2 Experimental method

The experimental flowchart is shown in Fig. 3. High-phosphorus iron ore concentrates were obtained by the

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