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JOURNAL OF IRON AND STEEL RESEARCH, INTERNATIONAL. 2016, 23(7): 655-660

Influences of Technological Parameters on Smelting-separation Process for Metallized Pellets of Vanadium-bearing Titanomagnetite Concentrates

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Abstract: The smelting-separation process for metallized pellets of vanadium-bearing titanomagnetite concentrates was studied. The influences of smelting temperature, smelting time, and the basicity of the metallized pellet on vanadium and iron recovery were investigated. The characteristics of titanium slag were analyzed using X-ray diffraction, energy dispersive spectroscopy, and mineralographic microscopic analysis. The results demonstrate that appropriate increases in smelting temperature and smelting time can improve the vanadium and iron recovery from metallized pellets and are beneficial for the slag-iron separation. Although increasing the basicity of the metallized pellet can considerably improve the vanadium and iron recovery, the TiO_2 grade of titanium slag was decreased. Under the optimal conditions, 90.17% of vanadium and 92.98% of iron in the metallized pellet were recovered, and the TiO_2 grade of titanium slag was 55.01%. It was found that anosovite, augite, spinel, glassiness, and metallic iron were the main mineral phases of the titanium slag.

Key words: metallized pellet; smelting; separation; titanium slag; vanadium; vanadium-bearing titanomagnetite concentrate

Vanadium-bearing titanomagnetite ore is a complex iron ore containing both vanadium and titanium and is widely distributed in vast worldwide reserves[1,2]. At present, more than 2×10^8 tons of vanadium-bearing titanomagnetite ore is present in the Panzhihua-Xichang (Panxi) area, China, accounting for more than 90% of titanium reserves in China and more than 35% of the worldwide titanium reserves[3]. The vanadium-bearing titanomagnetite and ilmenite concentrates are the two primary products obtained after the beneficiation process of the ore. In the past decades, vanadium-bearing titanomagnetite concentrates have been used as the main raw materials for blast furnace (BF) process in the Panxi area[4,5]. While most of the iron and a fraction of vanadium can be reduced into hot metal using the BF process, almost all of the titanium remains in the slag and forms a high-titanium slag with the TiO_2 content varying from 22 to 25 mass%. Currently, there is no effective low-cost method for extracting Ti from such slag[6,7]. Therefore, during the past decades, considerable attention has been focused on developing an alternative route for extracting all these three useful elements from vanadium-bearing titanomagnetite concentrates[8-10]. Both the rotary hearth furnace-electric arc furnace process, involving the direct reduction of vanadium-bearing titanomagnetite concentrate pellets using coal, and the smelting-separation process of the reduced specimen (called the metallized pellet) in an electric arc furnace have been extensively studied[11-14]. Currently, researchers have primarily focused on the direct reduction of vanadium-bearing titanomagnetite concentrate pellets using coal[15-21] and less attention has been payed to the smelting-separation process of metallized pellets. In this study, the smelting-separation process for metallized pellets of titanomagnetite concentrates was investigated. The influences of factors such as smelting temperature, smelting time, and basicity of the metallized pellet on the recovery rates of va-

Foundation Item: Item Sponsored by National Natural Science Foundation of China (51174122)
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nadium and iron were discussed, and the phase composition and mineralogical structure of titanium slags were analyzed.

1 Experimental

1.1 Materials

The vanadium-bearing titanomagnetite concentrates used in this study were obtained from Panzhihua, sichuan province in China. The metallized pellets were prepared using carbothermal reduction with vanadium-bearing titanomagnetite concentrates as the raw materials and coal as the reducing agent. The reduction temperature was 1250 ℃ and the reduction time was 30 min. The chemical composition of the metallized pellet is listed in Table 1. Phase characteristics of the sample were investigated using X-ray diffraction (XRD) with the obtained results shown in Fig. 1, indicating that the main crystalline phases were Fe and $Fe_{0.5}Mg_{0.5}Ti_2O_5$. The binary basicity (w_{CaO}/w_{SiO_2}) of the metallized pellet could be adjusted by adding CaO. According to the previous experimental results obtained by Ding et al.[22], the addition of CaO had only a weak effect on the carbothermal reduction under these experimental conditions. For this reason, the effect of CaO addition on the metallized pellet was not investigated in this study.

Table 1 Chemical composition of the metallized pellets mass%

TiO_2	TFe	MFe	FeO	CaO	MgO	SiO_2	Al_2O_3	V_2O_5	C	S
17.26	59.46	52.67	8.73	0.82	3.08	6.08	4.13	1.00	3.59	0.14

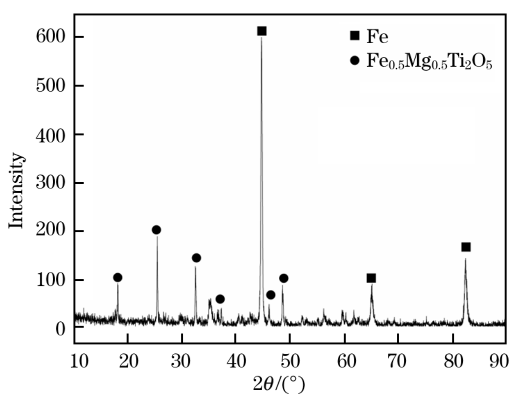

Fig. 1 XRD pattern of the metallized pellets

1.2 Experimental procedure

The metallized pellets were placed in a graphite crucible with 100 mm in top aperture diameter, 60 mm in bottom diameter, 80 mm in height, and 10 mm in wall thickness to provide a reducing atmosphere. The smelting-separation experiments were performed in a high-temperature box resistance furnace using the following processing parameters: the smelting temperatures were 1500, 1525, 1550, and 1575 ℃; the smelting time was 15, 30, 45, and 60 min; and the basicity of the metallized pellets was approximately 0.1, 0.3, 0.6, 0.9, and 1.2. The diameter of the metallized pellet was approximately 25 mm and the total mass of each specimen was approximately 200 g. The crucible was then inserted quickly into the combustion chamber when the furnace temperature reached the set smelting temperature. Smelting time was calculated when the furnace temperature returned back. After smelting-separation, the crucibles were extracted from the furnace and quickly cooled in air, and then the metal and slag were analyzed. The phase composition and mineralogical structure of the titanium slag were analyzed using XRD and a mineralographic microscope, respectively. The vanadium and iron contents of the iron nuggets as well as the TiO_2 content of titanium slag were determined via chemical analysis. The formula for calculating the vanadium and iron recovery rates is as follows:

$$R_e = \frac{M_e}{O_e} \times 100\% \tag{1}$$

where, R_e represents the recovery rate; and M_e and O_e are the mass of the element in the metal and in the metallized pellet, respectively.

2 Results and Discussion

2.1 Effect of smelting temperature

The effect of smelting temperature on the smelting-separation process of the metallized pellet was studied in the temperature range of 1500−1575 ℃ and constant smelting time of 30 min, and the basicity of the metallized pellet was approximately 0.1. The phase compositions of the titanium slag samples after smelting-separation at various temperatures are shown in Fig. 2. From Fig. 2, it can be found that $(Mg_{0.6}Ti_{2.4})O_5$ (anosovite) and Fe are the main phases of the titanium slag, with no obvious changes in phase compositions when increasing the smelting temperature. This indicates that the anosovite solid solution, which is the primary useful mineral in the titanium slag,