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Preparation and Metallurgical Analysis of High Activity Burnt Lime for Steelmaking

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Abstract: Burnt lime is an important material in steelmaking and its activity degree is a key factor for liquid steel quality. The burnt lime was made by the calcination of limestone in a high pressure electric furnace. The burnt lime mineralogical phases and micro-morphologies were characterized by X-ray diffraction (XRD) and field emission scanning electron microscopy (FE-SEM). The burnt lime activity degree was determined by acid-base titration, the burnt lime pore distribution was measured by mercury intrusion porosimetry (MIP), and the thermal effect of a mixture of burnt lime and slag was measured by differential scanning calorimetry (DSC). The results showed that the CaO grain size and pore size of burnt lime made under high pressure were larger than those of burnt lime made under atmospheric pressure. The CaO grain size and pore size increased and the laminate phenomenon also occurred clearly under high pressure. The activity degree of burnt lime made under high pressure was greater than that made under atmospheric pressure. The maximum activity degree was 437 mL for burnt lime made under a pressure of 0.4 MPa. For the same ratio of CaO to SiO_2, the melting temperature, hemisphere temperature and fluidity temperature of slag decreased with increasing burnt lime activity degree. The higher the activity degree the burnt lime had, the better the slag forming occurred. It was advantageous for $2CaO \cdot SiO_2$ and $3CaO \cdot SiO_2$ forming at lower temperatures if the burnt lime activity degree was increased.

Key words: burnt lime; high pressure calcination; activity degree; physical property; slag performance

Burnt lime has been used extensively in the metallurgical industry, and it has irreplaceable functions in steelmaking, secondary refining, sintering and flue gas desulfurization[1-6]. The burnt lime performs important functions such as the slag forming process, dephosphorization and desulfurization, shortening melting time and reducing material consumption in the steelmaking process[7,8]. The burnt lime could increase manganese yield, reduce the silicon content, and increase the economic index in the production of high carbon ferromanganese[9,10]. In addition, the burnt lime as the effective material is used to increase the sinter strength and the sinter yield in the sintering process[11]. Therefore, how to improve the burnt lime quality and properties is a research emphasis for metallurgical workers and experts.

At present, industrial burnt lime is mainly produced by shaft kilns, MAERZ kilns and rotary kilns under atmospheric pressure. For these kilns, the burnt lime activity degree varies in the range of 200 mL to 380 mL[12-14]. In theory, the activity degree of burnt lime (pure CaO) should be 446 mL, so improving lime activity degree further is possible. Therefore, much work has been done to improve lime activity degree by workers and experts. In this work, burnt lime was produced by calcining limestone in a high pressure electric furnace. The micro-morphology, activity degree, pore size distribution, slaking process

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and the slag performance of burnt lime made under different pressures were discussed. The research purpose was to obtain high activity lime and define the calcining method.

1 Experimental

1.1 Preparation of burnt lime

Limestone is the main material to produce burnt lime through a complicated process. The limestone in this research was obtained from Tangshan Iron and Steel Company. The contents of the main components of the limestone are shown in Table 1. The mineralogical phases of limestone were determined by D/MAX2500PC X-ray diffraction (XRD, Rigaku Corporation, Japan) and are shown in Fig. 1(a). The micromorphologies were observed by S-4800 field emission scanning electron microscopy (FE-SEM, Hitachi, Japan) and are shown in Fig. 1(b).

According to Table 1 and Fig. 1, calcite ($CaCO_3$) was the only mineralogical phase in the limestone and the microstructure was dense.

Table 1 Composition of limestone mass%

SiO_2	CaO	MgO	CO_2	S	P
2.71	47.88	5.02	42.86	0.05	0.0065

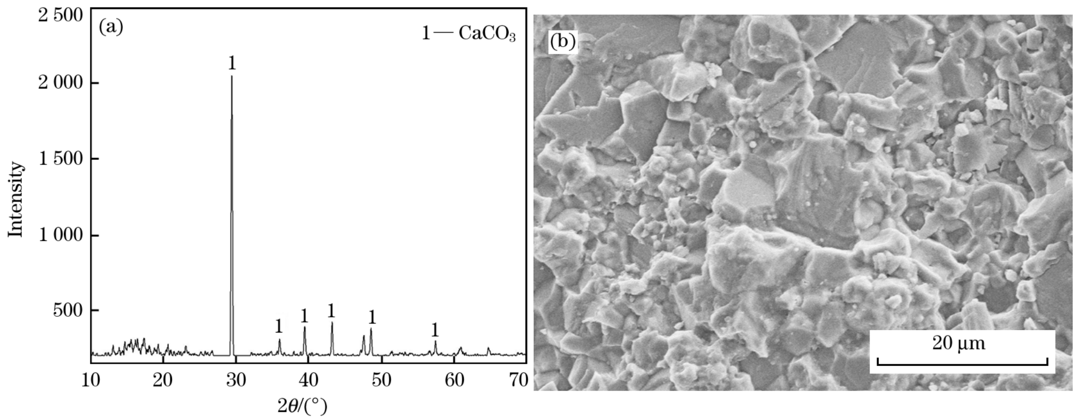
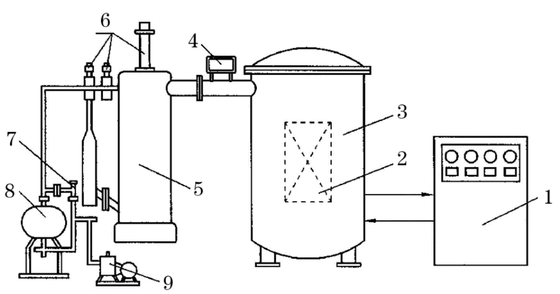


Fig. 1 XRD spectrum (a) and FE-SEM micrograph (b) of limestone

The burnt lime was made by the calcination of limestone at 1150 ℃ in a high pressure electric furnace of which the schematic drawing is shown in Fig. 2. The pressure varied from 0.1 MPa to 0.5 MPa by increment of 0.1 MPa.

The calcining procedure is described as follows: limestone with sizes of 10—20 mm in a crucible was put into the electric furnace and a vacuum was created in the electric furnace by the pump. High purity N_2 gas was injected into the furnace until the defined pressure reached. The furnace was heated to the defined temperature and kept thermally insulated for 2 h; then, the furnace was cooled down to room temperature. After the N_2 gas was released, the crucible was taken out. The limestone was then calcined to burnt lime and it was stored in a dry container.



1—Furnace temperature measurement and control cabinet; 2—Crucible; 3—Vacuum furnace; 4—Vacuum gauge; 5—Oil diffusion pump; 6—Vacuum valve; 7—Bypass; 8—Lobed element pump; 9—Mechanical pump.

Fig. 2 Schematic drawing of making burnt lime under high pressure

1.2 Properties measurement of burnt lime

The burnt lime activity degree was determined by acid-base titration. A sketch of the hydrochloric acid-base titration measurement apparatus is shown in Fig. 3. The measuring procedure was as follows: 50 g burnt lime with sizes of 1—5 mm was put into deionized water at 40 ℃ in a 2 L beaker. The suspension was stirred by a glass bar and 1 $g \cdot L^{-1}$ phenolphthalein reagent was added until the suspension turned red. When the red suspension was stirred at 300 $r \cdot min^{-1}$, 4 $mol \cdot L^{-1}$ hydrochloric acid drops were added into the suspension. When the red color disappeared, the hydrochloric acid drops were recorded. Once the solution turned red again, acid drops were again added to the suspension continuously, until the red color disappeared once more. The hy-