EFFECTS OF ROASTING PRETREATMENT IN INTENSE MAGNETIC FIELD ON DIGESTION PERFORMANCE OF DIASPORIC BAUXITE

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Abstract

This paper investigates the changes of phase and apparent morphology under the combined effects of an intense magnetic field and temperature field and the effect law of different roasting conditions on the digestion performance of roasted diaspore. The results indicated that roasting pretreatment under high magnetic fields can change the microstructure and improve the digestion properties of bauxite. The reasonable roasting conditions with intense magnetic field are as follows; the roasting temperature is 550°C, roasting time is 60min and the magnetic field intensity is 6T. The digestion rate of alumina of the roasted ore is 84.17% and the digesting liquid ratio is 1.39 while the digesting temperature is 190°C with the digestion time of 60mins. The digestion rate of alumina of the roasted ore increases to higher 52.85% than that of the raw ore , but the digesting liquid ratio is decreased to lower than 0.99 of the raw ore under the above roasting conditions. The digestion temperature of roasted ore decreases by 30°C compared to the raw ore.

Introduction

Chinese reserves of bauxite include vast quantities of diaspore with a high content of aluminum and silica and low content of iron, which at present are sub-economic due to the high levels of reactive silica that require high digestion temperatures and cause expensive losses of caustic soda during Bayer processing. At present there are many intensive leaching methods for diasporic bauxite, such as roasting pretreatment – low temperature leaching technology, mining added sweetening technology and so on.

In order to promote the technology of producing alumina from Chinese bauxites, Northeastern University has presented an approach to roasting pretreatment of bauxite using intense magnetic fields. The coupling effect of a magnetic field and a temperature field is able to improve the morphology of bauxite ore and chemical speciation of the main phases, leading to activation of the ore and reducing the digestion conditions needed for the bauxite. In this paper, the effect of process conditions on digestion performance of bauxite were studied during a roasting pretreatment with an intense magnetic field. This research will provide a theoretical basis of improving digestion for the alumina industry[1~5].

Experimental

Diasporic bauxite from Henan Province was used. The chemical and mineralogical compositions are shown in Table I and Table II, respectively. Mineralogical analysis of the initial sample (Fig.1) was performed on a PW3040/60 X-ray diffractometer with scanning angle from 5 to 90 degree, giving the result that the bauxite primarily consists of diaspore as well as other minor minerals such as hematite, kaolinite and anatase.

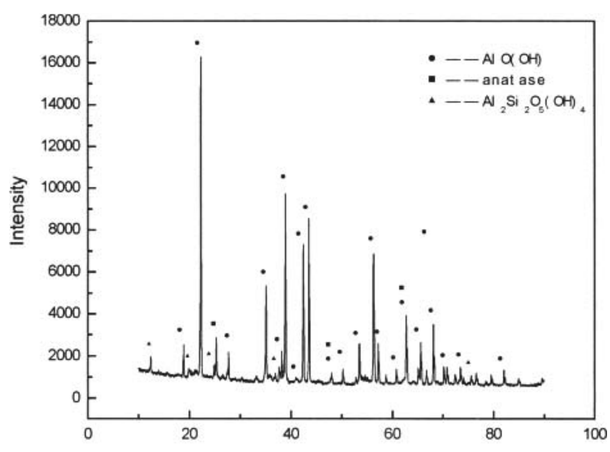


Fig.1 XRD pattern of raw ore

Table I Chemical compositions of diaspore

Chemical composition	Al_2O_3	SiO_2	Fe_2O_3	CaO	Na_2O	LOI
Content/%	67.57	7.14	5.54	0.90	0.31	13.85

Table II Mineralogical composition of bauxite						
Mineralogical composition	Diaspore	Hematite	Goethite	Quartz	Anatase	Kaolinite
Content%	69.4	3.1	2.7	1.0	3.7	12.1

The solution used in these experiments is a sodium aluminate liquor. The concentrations of total alkali, caustic alkali and Al_2O_3 in the solution are about 239g/L, 221g/L and 125g/L respectively.

Roasting pretreatment experiment

The graphite crucible (Φ20 × 100mm) containing aliquots of sample was placed into the intense magnetic field generating device which was raised to the desired magnetic flux density ranging from 1 to 12T. Afterwards, the sample was heated. The temperature ranged from 300 to 600 °C. Once the roasting temperature was reached, the sample was left in the device for a certain time ranging from 5 to 60 minutes. After the roasting time elapsed, the device was cooled down to 150 °C. When the magnetic flux density was low enough, the crucible was removed from the device. The intense magnetic field roasting device is shown in Figure 2.

Fig.2 Intense magnetic field equipment (12T)

Digestion experiment

The digestion experiment was carried out in a WHFS-1 autoclave. Digestion time was 60min, and the content of CaO addition was 5% by weight. After digestion, the digested slurry was separated into solution and red mud by filtration. The concentrations of Al_2O_3 and Na_2O_K (concentration of caustic soda) in solution and the content of Al_2O_3 and SiO_2 in the red mud were determined by chemical analysis. The calculated formula for the molar ratio of the digestion solution is:

$$\alpha_k = 1.645 \times \frac{Na_2O_k}{Al_2O_3} \quad (1)$$

where Na_2O_k / Al_2O_3 is the mass ratio of Na_2O_k and Al_2O_3. The relative digestion rate of Al_2O_3 is expressed as:

$$\eta = \frac{(A/S)_O - (A/S)_r}{(A/S)_O} \times 100\% \quad (2)$$

where $(A/S)_o$ and $(A/S)_r$ are the ratio of alumina to silica in raw ore and red mud, respectively.

Results and discussion

Effect of roasting temperature

The effect of roasting temperature ranging from 300°C to 600°C on the digestion performance of treated ore was evaluated. It can be seen from Fig.3 that digestion rate of alumina increased and then decreased with increasing temperature. 550°C is considered as the optimum roasting temperature where the caustic ratio, the real digestion rate and the relative digestion rate were 1.39, 84.17% and 95.08%, respectively. It would require over 220°C for the initial bauxite to get the same level of digestion rate. When fixing the digestion temperature at 190°C, the digestion rate of the roasted ore increased by 52.38%, and the caustic ratio decreased by 0.99, in comparison to that of the raw ore which displayed a relative digestion rate of 31.32%. Consequently, the optimum roasting temperature in the intense magnetic field is 550°C.

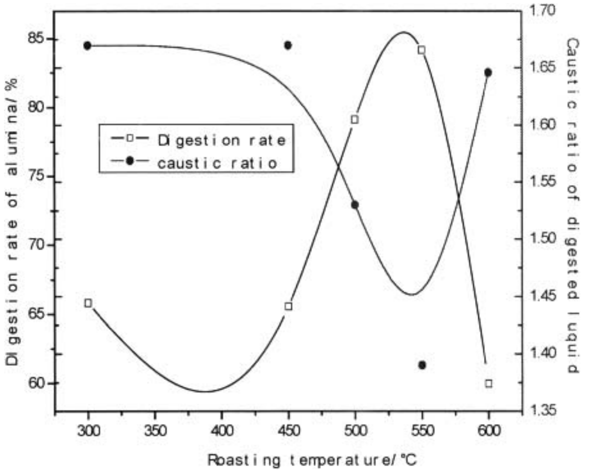


Fig. 3 Effect of intense magnetic field roasting temperature on digestion performance of diaspore

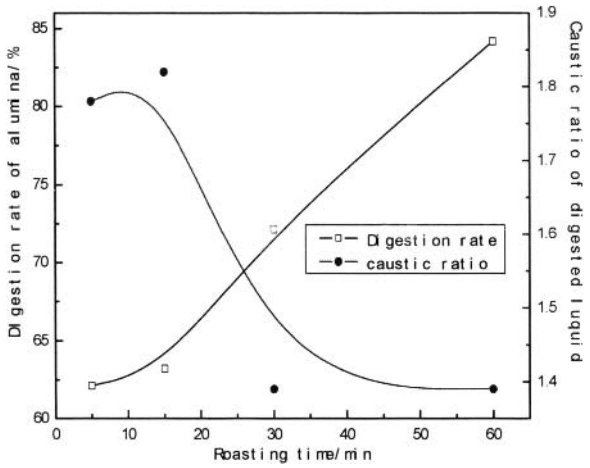


Fig. 4 Effect of intense magnetic field roasting time on digestion performance of diaspore

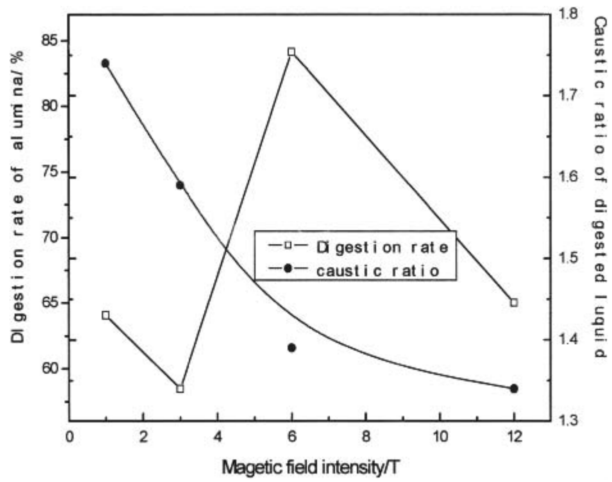


Fig. 5 Effect of magnetic field intensity on digestion performance of diaspore

Effect of roasting time

How the roasting time varying from 5 to 60 minutes impacts on the digestion rate of roasted bauxite was investigated. The diaspore was roasted in the magnetic field with intensity of 6T and roasting temperature of 550°C. The digestion condition was 190°C for digestion temperature, 60min for digestion time, 3.1 for caustic ratio of mother liquor, 220 g/l for caustic concentration and 5% for lime addition amount, respectively. Experimental results were shown in Fig.4.

The digestion rate of alumina improved rapidly with temperature increase, which reached a maximum of 95.08% at a roasting time of 60min. Meanwhile, the caustic ratio of digested liquid achieved a minimum of 1.39 under this condition. Thus, 60 minutes is the optimal roasting time.

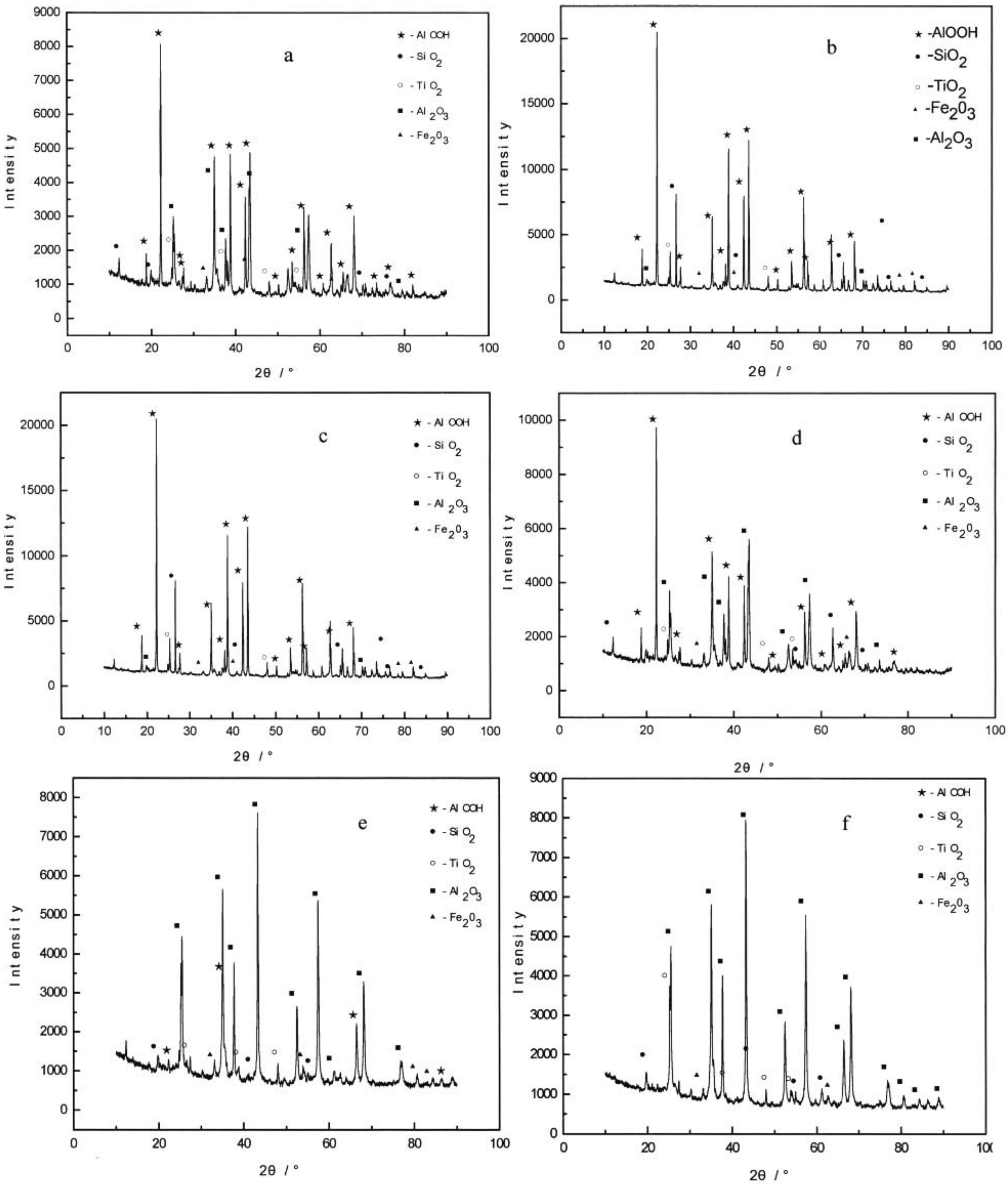
Effect of magnetic field intensity

The effect of magnetic field intensities, namely1T, 3T, 6T, 9T and 12T, on the microstructure characteristics and digestion performance of diaspore at roasting temperature of 550°C and roasting time of 30min, was investigated. The digestion condition was 190°C for digestion temperature, 60min for digestion time, 3.1 for the caustic ratio of mother liquor, 220 g/l for caustic concentration and 5% for amount of lime addition, respectively. The experimental results are shown in Fig.5.

The digestion rate of alumina achieves a maximum, while the caustic ratio of the digested liquid reaches the lowest value, when the magnetic field intensity is 6T. Above this value, digestion rate decreases with magnetic field intensity. The reason might be that the inner crystal structure of bauxite completely transformed when the magnetic field intensity is up to 6T. With the intensity going up, the orientation of the inner molecular structure is stable and the degree of induction of various compositions to the magnetic field goes to the extreme.

Mechanism analysis of pretreatment of intense magnetic field

Diaspore begin to dehydrate at 500°C, which leads to the breakage of the crystal chain structure and the replacement of the coordinated octahedron of $Al(O,OH)_6^-$ into a suspending state. Reaction activity of this structure is clearly much stronger. The Al^{3+} in the centre of the octahedron is exposed because of removal of OH^- and O^{2-} through roasting pretreatment. Because the crystal structure of the diaspore is significantly degraded, digestion performance of bauxite improved measurably. The crystal lattice of alumina transforms from the $Al(O,OH)_6^-$ octahedron of a *Pbnm* orthorhombic structure, to an AlO_6^- octahedron of *R3c* trigonal structure under the condition of roasting temperature of 550°C and roasting time of 60 minutes. The digestion conditions for pure corundum are much more demanding than that of diaspore, as the activity of the former is relatively low. Since a great deal of energy is needed to support the transformation of diaspore into pure corundum, the perfect crystal structure of pure corundum could not be generated before the roasting condition achieved. We infer that the alumina phase of the roasted ore is not a pure corundum but imperfect crystallized alumina in the transition state at roasting condition of 550°C, it is extremely beneficial for improving digestion performance, because a highly activite alumina of transition state exists in the roasted ore. XRD patterns of bauxite roasted at different temperatures are shown in Fig.6. Roasting pretreatment could improve the surface form of bauxite because of the appearance of porosity and crack, which enlarges the specific surface as measured by the method of nitrogen adsorption. The results of the specific surface of the roasted ore are shown in table 3, indicating that specific surface area reaches a maximum at a roasting temperature of 550°C, and above which, the value declines gradually with increasing roasting temperature. The increase of specific surface area enlarges the contact area between ore and liquid. So the reaction dynamic conditions are improved, and the leachability of the sample is enhanced [6]



A-raw ore ; B-300℃ ; C-450℃ ; D-500℃ ; E-550℃ ; F-600℃

Table III Effect of roasting temperature on surface area of diaspore (6T)						
Roasting temperature/°C	Raw ore	300	450	500	550	600
Surface area/$m^2 \cdot g^{-1}$	1.6205	8.7339	8.4351	38.7462	49.3558	51.0172

Because the magnetic susceptibility and the dielectric constant vary with specific minerals, the mineral phases in the ore will be influenced in different degrees by intense magnetic field during the roasting pre-treat process. On one hand, the value of Gibbs free energy of each phase will change, resulting in an impact on the stability of the mineral phase. On the other hand, an intense magnetic field also has an effect on the kinetics of phase transformation. The morphology of mineral phases with different magnetic properties would alter, which will affect the mineral structure and properties.

For the roasting of bauxite, proper temperature increases the internal energy, accelerates the molecular thermal motion and leads to lattice distortion and phase transition. So during the process, the energy of the magnetic field will have great influence on specific magnetic species and on the direction of thermal motion of molecules. It increases the internal active energy, the degree of phase instability, the lattice distortion and makes the phase transition less complete, so the leaching ability of the ore is enhanced.

When the intensity of the magnetic field reaches 6T, the temperature field and magnetic field interact with each other. The digestion rate decreases with the further increase of temperature. There are several possible reasons to explain this phenomenon. When the intensity of magnetic field is too high, the atoms and molecules will be oriented in a certain range according to the direction of the magnetic field[7~8]. So this will hinder the lattice distortion and the transitions of the crystal structure. This decreases the activity of roasted ore and leads to a decrease in digestion rate. So there should be an optimum magnetic intensity, rather than an infinitely high value.

Conclusions

(1) The digestion performance of diasporic bauxite is enhanced effectively by a roasting pre-treat in the presence of a magnetic field. After pre-treatment under appropriate conditions, the observed leaching temperature decreases by at least 30°C compared with the raw ore.

(2) The mechanism of the effect of intense magnetic field in the pre-processing is that the influence of magnetic field varies with mineral phase, due to the changes of magnetic susceptibility and dielectric constant for different minerals. It will affect the value of Gibbs free energy of different phases as well as the stability of the ore. When the intensity of magnetic field is high, the atoms and molecules will be oriented in a certain range according to the direction of the magnetic field. In higher ranges, the activation effect is weak.

(3) The optimal conditions of intense magnetic field pre-treatment are determined as temperature of 550°C, roasting time of 60 minutes, magnetic intensity of 6T. When the roasted ore was digested in the sodium aluminate solution with a mole ratio of 3.1 and alkali concentration of 220g/L at 190°C for 60 minutes, the mole ratio of digestion solution decreases to 1.39 and the absolute and relative digestion leaching rates are 84.17% and 95.08%, respectively.

Acknowledgement

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