Effects of Roasting Pretreatment in Intense Magnetic Field on Digestion Performance of High Iron Bauxite

LV Guozhi, ZHANG Ting'an, ZHANG Xuhua, LIU Yan, DOU Zhihe, LI Yan, HE Jicheng

ZHANG Ting-an, Professor, E-mail: zta2000@163.net,Shenyang, Liaoning 110004, China

LV Guo-zhi, Lecture, E-mail: lvgz@smm.neu.edu.cn, Shenyang, Liaoning 110004, China

ZHANG Xuhua, Master, E-mail: zta2000@163.net, Shenyang, Liaoning 110004, China

(Key Laboratory of Ecological Utilization of Multi-metal Intergrown Ores of Ministry of Education, School of Materials and Metallurgy, Northeastern University, Shenyang, Liaoning 110004, China)

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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. The effect of different roasting conditions on the digestion and settling performance of high-iron diaspore is also studied here. The results indicated that roasting pretreatment under high magnetic fields can change the microstructure of bauxite, hence improving its digestion properties. The optimum roasting conditions in intense magnetic field for high-iron bauxite are: the roasting temperature is 500℃, roasting time is 60min and the magnetic field intensity is 9T. The digestion rate of alumina for roasted ore is 71.82% when digested at 210°C for 60min with the digesting liquor ratio of 1.69, which is ~20% higher than that of raw ore. The settling performance of the digested slurry is also improved significantly when using roasted bauxite treated in intense magnetic field.

Introduction

The dominant bauxite in China is diaspore with a high content of aluminum and iron, which need high digestion temperatures during Bayer process. 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 alumina producing from Chinese bauxites, Northeastern University has developed an approach to roast pretreat the bauxite in intense magnetic fields. The coupling effect of magnetic field and temperature field is able to improve the morphology of bauxite and chemical composition of the main phases, leading to the activation of ore, hence reducing the digestion requirement for bauxite. In this paper, the effects of process conditions, such as roasting pretreatment temperatures and times, the intensity of magnetic field, on the digestion performance of bauxite with high iron content were studied. The effect of intense magnetic field on the iron existing status and their effect on the digestion and the settlement properties of red mud were also further investigated. This research will provide a theoretical basis of improving digestion for the alumina industry [1~5].

Experimental

Diasporic bauxite from Guangxi Province was used in this experiment. The chemical composition and mineralogy of this bauxite are shown in Table I and Figure 1, respectively. The mineralogy is measured by a PW3040/60 X-ray diffractometer with scanning angle from 5 to 90 degree. It shows that the bauxite consists primarily of diaspore and hematite as well as some other minor minerals such as kaolinite and anatase.

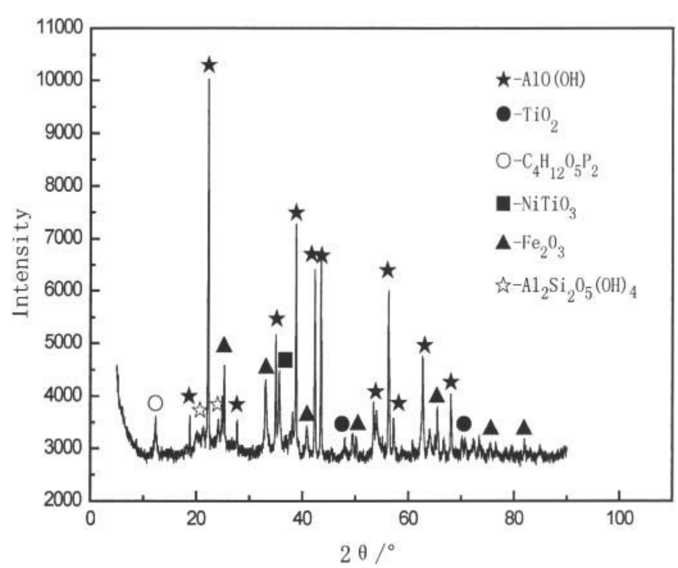


Fig.1 XRD pattern of raw ore

Table I Chemical compositions of diaspore						
Chemical composition	Al_2O_3	SiO_2	Fe_2O_3	TiO_2	CaO	LOI
Content/%	49.09	7.11	26.36	2.99	0.55	14.00

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

Roasting pretreatment experiment

The graphite crucibles with bauxite samples were placed into the intense magnetic field generating device, which could raise the magnetic flux density to the desired value from 1 to 12T. The samples were then heated to the desired temperature from 300°C-600°C and hold for 5-60min. The device was cooled down to 150°C after the roasting treatment was completed. The crucibles with sample were taken out from the device when the magnetic flux density was low enough. The intense magnetic field roasting device is shown in Figure 2.

Digestion experiment

The digestion experiment was carried out in a WHFS-1 autoclave. Digestion time was 60min, and the amount of CaO added 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 amount of Al_2O_3 and SiO_2 in the red mud were determined by chemical analysis.

The formula for the molar ratio calculation 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 to 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 magnetic field intensity

The effect of magnetic field intensities, namely0T, 6T, 8T, 9T and 10T, on the microstructure and digestion performance of high-iron bauxite roasted at 500°C for 60min, was investigated. The digestion was done at 210°C for 60min in mother liquor with the caustic molar ratio of 3.0, caustic concentration of 220g/l and 5 wt% of lime loading. The experimental results are shown in Fig.3.

Fig.2 Photo of the intense magnetic field equipment (12T)

The maximum digestion rate of alumina and the minimum caustic ratio of the digested solution are achieved at the magnetic field intensity of 9T. Above this value, digestion rate decreases with the increase of magnetic field intensity. The reason might be that the inner crystal structure transformation of bauxite is completed when the magnetic field intensity goes up to 9T. The orientation of the inner molecular structure is already stabilized and the induction of compositions in bauxite to the magnetic field reaches the limit at this point. Therefore, further increasing the intensity of magnetic field won’ t results in further improving, and the high iron content of bauxite might shield the magnetic field effect during pretreatment when the magnetic field intensity is higher than 9T.

Effect of roasting temperature

The effect of roasting temperature ranging from 450°C to 550°C on the digestion performance of treated ore was evaluated and the results were shown in Fig.4. It illustrated that digestion rate of alumina is changing with the roasting temperature significantly. The optimum roasting temperature is 500°C where the caustic ratio and the relative digestion rate were 1.69 and 71.82% respectively, which is about 20% higher than the digestion rate of the bauxite without pretreatment.

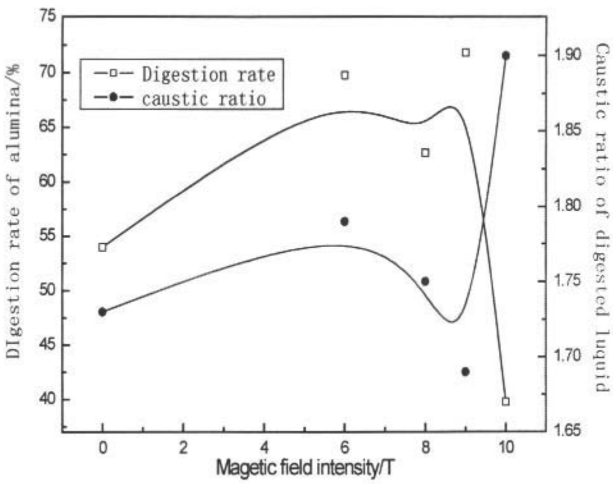


Fig. 3 Effect of magnetic field intensity on digestion performance of high iron bauxite

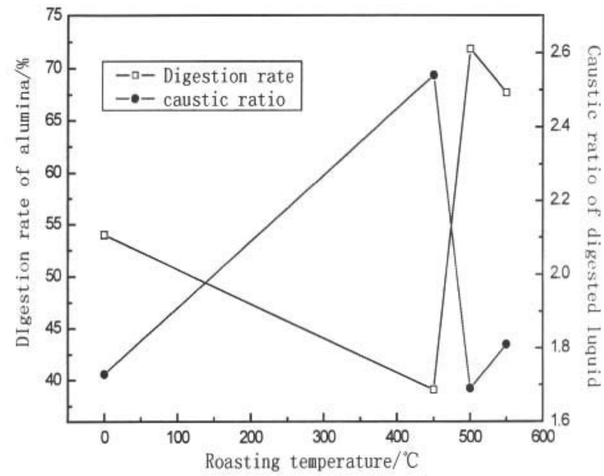
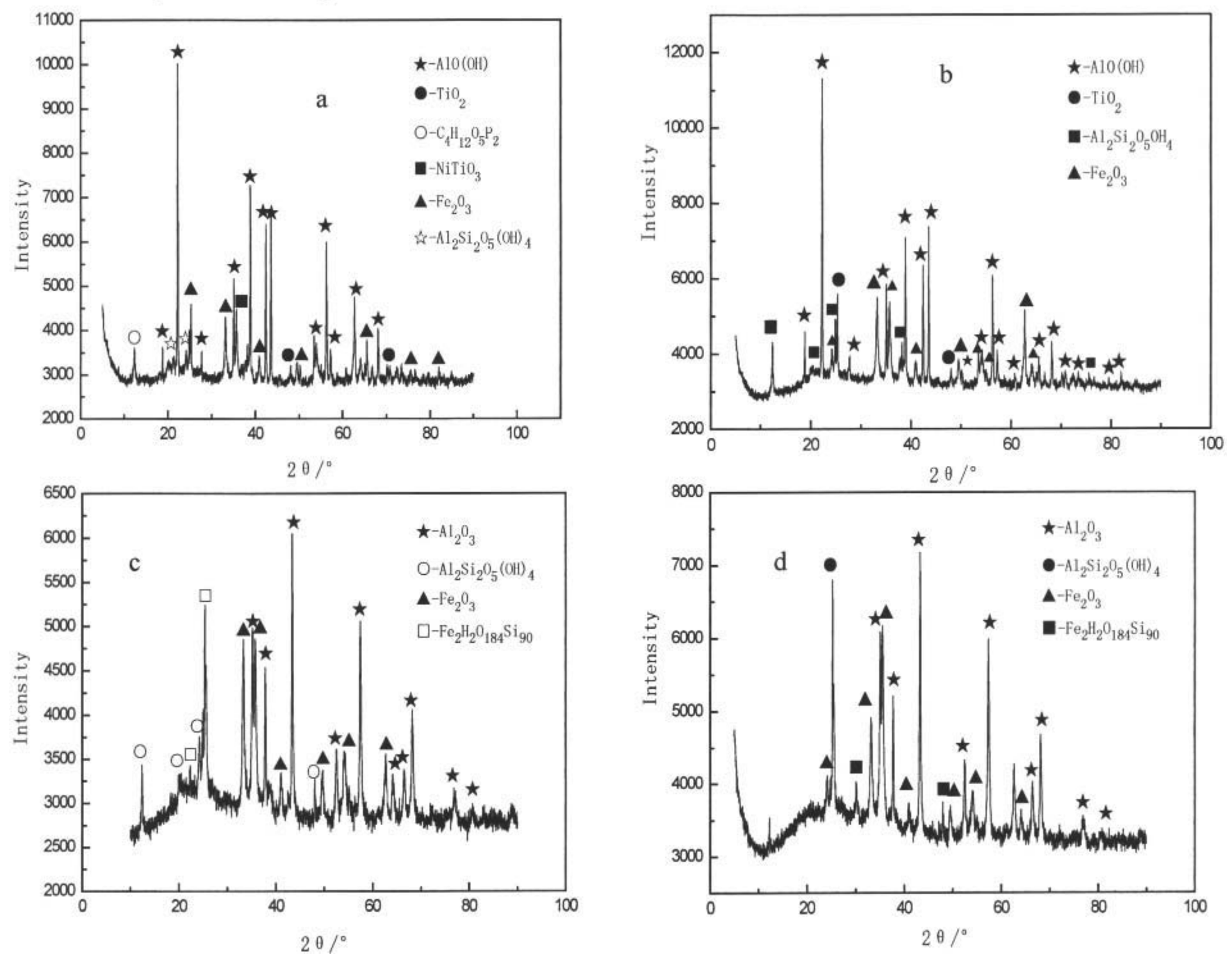


Fig. 4 Effect of roasting temperature on digestion performance of high iron bauxite



a-raw ore; b-450°C; c-500°C; d-550°C

Fig.5 XRD patterns of bauxite before and after roasted at different temperatures

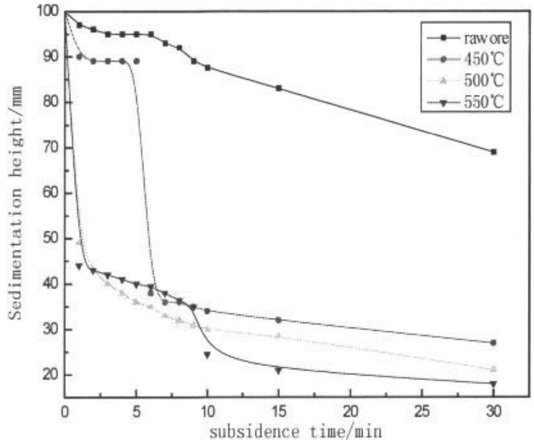


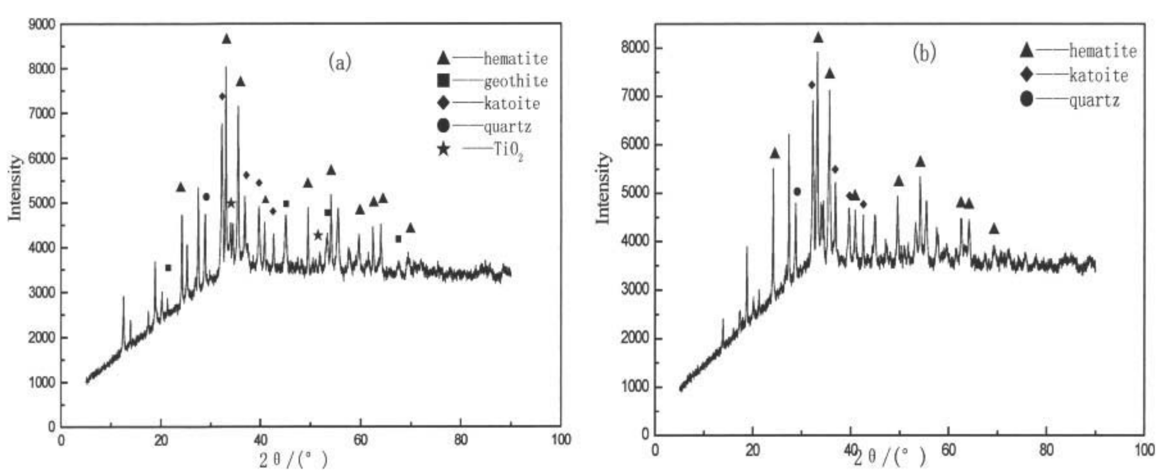
Fig.6 Effect of roasting temperature on the settlement of red mud

XRD patterns of raw and roasted bauxite are shown in Figure 5. From which the phase transformation of high iron bauxite during roasting process can be observed obviously. The diaspore of AlOOH in the raw bauxite transforms into α-Al_2O_3 after pretreatment. The reaction is shown as:

$$2AlOOH=Al_2O_3+H_2O \qquad (2)$$

The transformation starts at 500ºC, which leads to the breakage of the bonds in crystal structure and results in the replacement of the coordinated octahedron of $Al(O,OH)_6$ into a suspending state. The reacting ability of this structure is clearly much higher. The Al^{3+} in the centre of the octahedron is exposed due to the removal of OH^- and O^{2-} during roasting pretreatment. All the aforementioned changes in the structure of diaspore significantly improved its digestion performance. 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 500°C and roasting time of 60 minutes. The digestion performance was improved at this pretreatment condition. However, when further increase the roasting temperature to above 550°C, the final transformation product is corundum which is a stable state of Al_2O_3, hence the digestion performance decreased at this pretreatment condition.

Settling results of red mud from raw and roasted bauxites at different temperature are shown in Figure 6. It indicates that the settling speed of digested slurry from roasted bauxite is much faster than that of the raw ore. The settling speed of digested slurry from bauxite roasted at 450°C for 60min is close to that of the raw ore at the first 5min of settling process, but later the settling speed of the roasted ore is faster than the raw ore dramatically. The XRD patterns of the red mud from raw ore and roasted ore are shown in figure 7. It shows that the iron in the red mud from raw bauxite exists in both hematite and goethite type, while the iron in the red mud from roasted bauxite exists only in the type of hematite, which is more stable than goethite. Thus the negative effect of iron on the settlement of red mud slurry is reduced by the roasting process.



(a)-raw ore; (b)-roasted ore

Fig.7 XRD pattern of red mud

Effect of digestion temperature on digestion and settlement properties

The digestion efficiency of roasted ore at different digesting temperature and the relative caustic ratio are studied, and the digestion conditions are: digestion temperature of 210~250℃ and digestion time of 60mins. The digestion results are shown in Table II, which shows that the digestion efficiency goes up to ~ 92% at the digestion temperature of 250℃.

Table II Chemical compositions of diaspore

Digestion temperature/℃	Chemical content of red mud		Relative digestion rate /%	A+
	Al_2O_3 /%	SiO_2 /%		
210	30.10	11.30	71.82	1.69
230	19.52	8.48	77.95	1.46
250	19.84	13.69	92.39	1.50

The settlement properties of red mud slurry obtained at different digestion temperatures are showed in Figure 8. It indicates that the settling performance of digested slurry decreased with the increase of digestion temperature. The reason might be that the rise of digestion temperature increases the digestion efficiency of alumina, but reduce the particle size of red mud. The particle sizes of the red mud at different digestion temperature are showed in Figure 9. It illustrates that the average particle size of red mud moves left to the small size range.

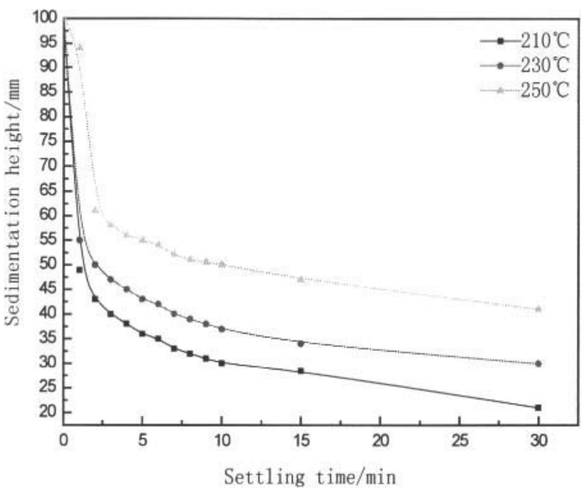
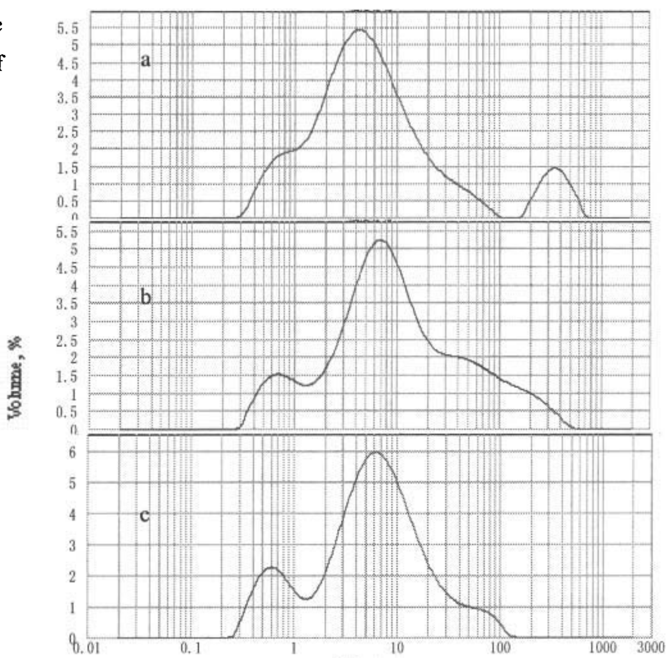


Fig.8 Effect of digestion temperature on the settlement of red mud



a-210°C; b-230°C; c-250°C

Fig.9 Effect of digestion temperature on particle sizes of red mud

Conclusion

(1) Roasting pretreatment under high magnetic fields can change the microstructure and improve the digestion properties of bauxite. The optimum roasting conditions in intense magnetic field are: the roasting temperature is 500ºC, roasting time is 60min and the magnetic field intensity is 9T.

(2) The digestion rate of alumina of the roasted ore, which is about 20% higher than that of the raw ore, at the optimum condition is 71.82% and the molar ratio of digesting liquid is 1.69 when digested at 210 °C for 60 mins. The optimal digestion condition of roasted ore is: the digestion temperature of 250°C, the digestion time of 60min and lime loading of 5 wt%.

(3) The settlement performance of red mud is improved significantly by roast pretreating bauxite. The settling

performance of digested slurry decreases with the increase of digestion temperature.

Acknowledgement

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