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APPROPRIATE REDUCTION AND Fe-Al SEPARATION OF HIGH IRON GIBBSITE

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Abstract

High iron gibbsite is a Fe-Al composite ore with quite big reserves in China, in which superfine aluminum and ferrous minerals are conjoint with each other. Thus, they are difficult to separate through physical beneficiation. In order to meet iron and aluminum consumption, a new process was proposed, in which gibbsite samples and pulverized coal were mixed uniformly, reduced isothermally at high temperature, cooled rapidly and then dressed by magnetic separation. The effects of reduction conditions, including reduction time, reduction temperature and FC/O (mole ratio), were investigated. The results revealed that regarding samples with 34.68% iron and 23.85% alumina, metallic iron concentrate with 78.23% iron and non-magnetic product with 53.32% alumina were obtained. The yielding ratio of iron and alumina are 89.24% and 86.09% respectively. Metallic iron concentrate can be used as steelmaking burden by further treatment, and alumina can be further extracted from the non-magnetic product.

Introduction

With rapid development of the national economy, the lack of iron and aluminum ore sources has been an important bottleneck for steel and aluminum industry development, respectively [1-2]. As one kind of iron-rich gibbsite, high iron gibbsite spreads over some provinces in China. The national reserve attains to more than 1.5 billion tons, and only Guangxi province owes over 200 million tons [3-4]. With the aim of achieving comprehensive utilization of high iron gibbsite, many studies have been carried out, and several treatment processes have been presented [5]. Owing to the disseminated agglutination and paragenesis of Fe and Al in high-iron gibbsite, agglomeration, dressing and blast furnace smelting are extremely difficult, and separation effects of Fe and Al are relatively low. So far, the high iron gibbsite is not efficiently utilized and even idle. Under the above background, a new process of high-iron gibbsite appropriate reduction-dressing separation is put forth in this study. Based on the characteristics analysis of raw materials, the effects of process parameters, including magnetic flux intensity, reduction temperature, reduction time, FC/O ratio and particle size of high iron gibbsite on process index are systematically studied.

Experiment

Raw materials

The high iron gibbsite sample used in this study was obtained from Guangxi Province and chemical compositions are listed in Table 1. For this sample, the content of total iron, alumina and silica is 34.68%, 23.85% and 7.16%, respectively, and A/S is 3.33. That is to say, the sample has the characteristics of high iron, high silica and low A/S, not suitable to produce alumina by Bayer process.

The chemical compositions of pulverized coal used in the test are listed in Table 2. The fixed carbon content is 43.45, and V_{ad} 33.6.

Table 1 Chemical composition of high-iron gibbsite sample

Components	TFe	Fe_2O_3	SiO_2	Al_2O_3	CaO	MgO	S	P	LOI
Content (wt %)	34.68	49.21	7.16	23.85	0.01	0.21	0.03	0.12	17.50

Table 2 Industry analysis on pulverized coal used in the test

Components	FC_d	A_{ad}	V_{ad}	$S_{t,d}$	M_{ad}
Content (wt %)	43.45	14.60	33.86	0.40	8.09

Experiment procedure

The experimental procedure is shown in Fig. 1. Before the experiments, the high iron gibbsite and pulverized coal were matched, with mole ratio of fixed carbon to reducible oxygen (indexed as FC/O) of 1.0, 1.5, 2.0, 2.5 and 3.0, respectively. Then, all the samples were mixed uniformly. Appropriate reduction was performed in a closed $MoSiO_2$ muffle resistance furnace, whose temperature control accuracy is within ±5℃. In each test, the mixed samples were put into a closed graphite crucible and reduced in the furnace under the preset temperature. Once the reduction experiment finished under the preset time limit, the samples were taken out and cooled rapidly while isolated from air. Then, the cooled samples were ground to the size of less than 0.075 mm, and separated into metallic iron and non-magnetic product by magnetic separator with certain magnetic flux intensity.

During the tests, the experimental conditions of reduction-separation, namely magnetic flux intensity, reduction temperature, reduction time, FC/O ratio and particle size of high iron gibbsite were changed according to the designed scheme.

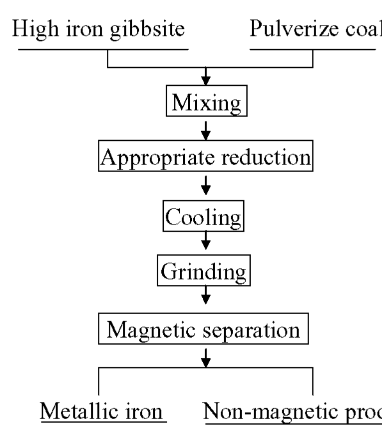


Fig. 1 Experimental procedure of appropriate reduction and Fe-Al separation of high iron gibbsite

The metallization degree M of metallic iron product is calculated by the following formula:

$$M=(MFe/TFe)\times 100\% \quad (1)$$

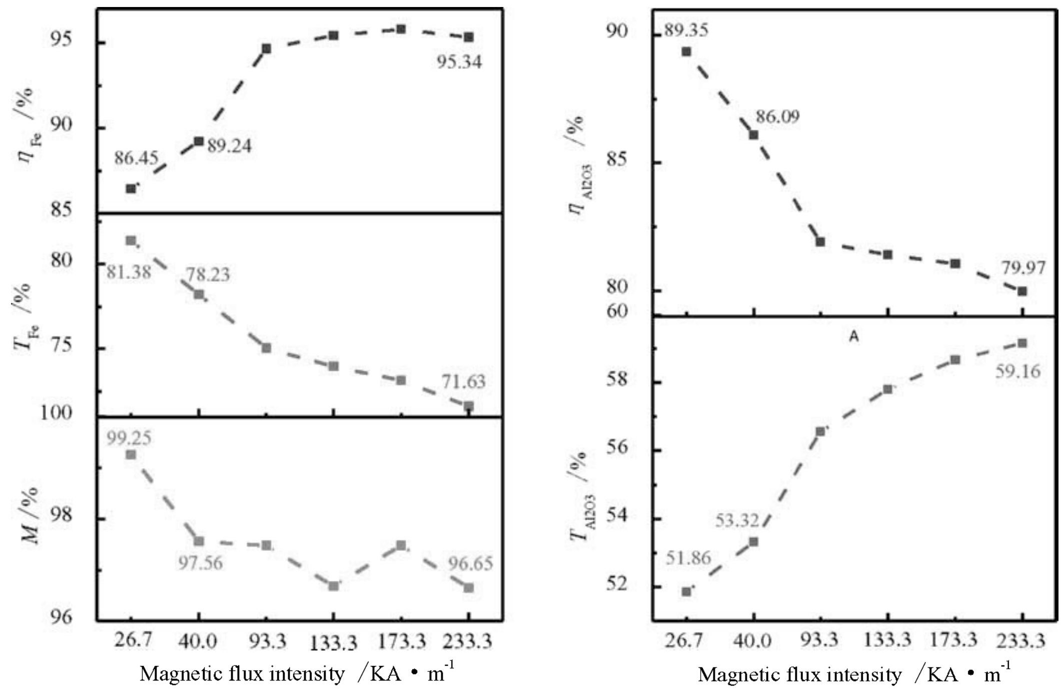
Where, *TFe* is total iron content, *MFe* is metallic iron content; both were achieved through chemical analysis.

In order to evaluate the efficiency of the new process put forth in this paper, the yielding rate of iron (η_{Fe}) and alumina (η_{Al2O3}) were taken into account, where η_{Fe} is the proportion of total iron amount in metallic iron product after separation to the of total iron amount in high iron gibbsite before reduction, while η_{Al2O3} is proportion of alumina amount in non-metallic product after separation to the alumina amount in high iron gibbsite before reduction.

Results and discussion

Effects of magnetic flux intensity

Fig. 2 gives that the effects of magnetic flux intensity on the process index (η_{Fe} and η_{Al2O3}). The experimental conditions includes reduction temperature of 1400℃, reduction time of 180 min, FC/O ratio of 2.0, gibbsite particle size of less than 2.0 mm(indexed as -2.0mm), and magnetic flux intensity varying from 26.7 KA/m to 233.3 KA/m.



(a) Metallic iron (b) Non-metallic product

Fig. 2 Effects of magnetic flux intensity on the process index

From Fig. 2, it can be seen that the yield rate of iron (η_{Fe}) increased, while the yielding rate of alumina (η_{Al2O3}) decreased with the magnetic flux intensity increasing. The range from 26.7 KA/m to 40 KA/m was considered as the optimum magnetic flux intensity. When the magnetic flux intensity was 40 KA/m, the yield of iron (η_{Fe}) and alumina (η_{Al2O3}) in the tests were 89.24% and 86.09% respectively, total iron content (*TFe*) in metallic iron and alumina (T_{Al2O3}) content in non-metallic product were 78.23% and 53.32% respectively. Consequently, the appropriate magnetic flux intensity is from 26.7 KA/m to 40 KA/m, and the optimum magnetic flux intensity is 40 KA/m.

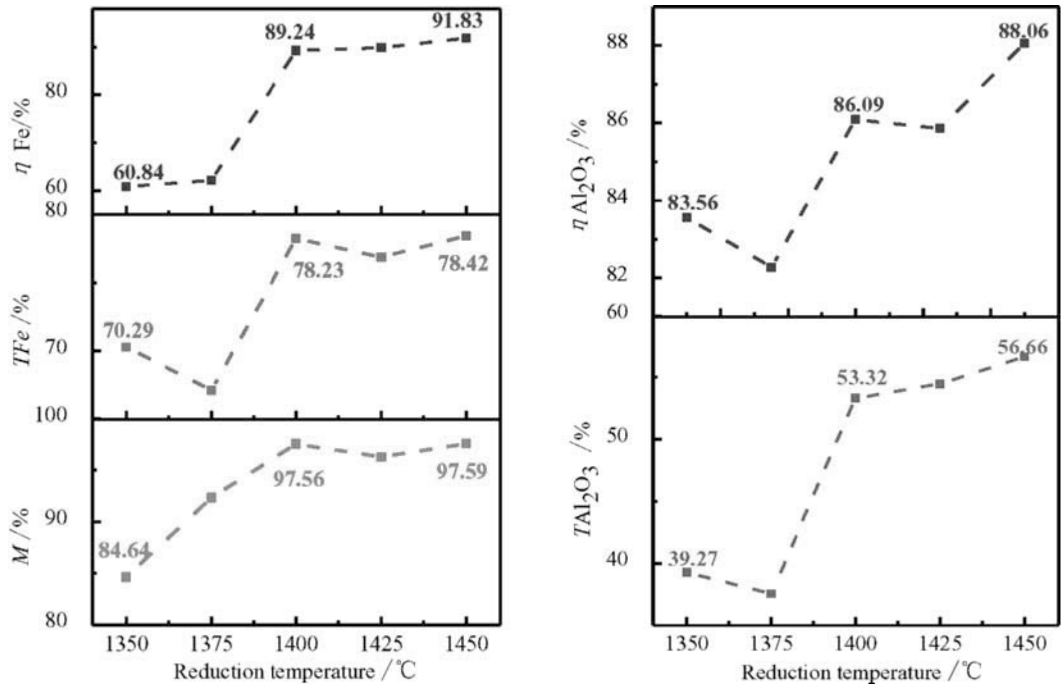
Effects of reduction temperature

Fig. 3 gives that the effects of reduction temperature on the process index. The experimental conditions includes the magnetic flux intensity of 40 KA/m, reduction time of 180 min, FC/O ratio of 2.0, gibbsite particle size of -2.0 mm and reduction temperature, namely 1350℃, 1375℃, 1400℃, 1425℃ and 1450℃. From Fig. 3, it can be seen that all process indexs were increased with reduction temperature increasing. So increasing the reduction temperature was beneficial for iron and alumina separation. When the reduction temperature was 1400℃, the yield of iron (η_{Fe}) and alumina (η_{Al2O3}) in the tests were 89.24% and 86.09% respectively, the content of total iron (*TFe*) in metallic iron and alumina (T_{Al2O3}) in non-metallic product were 78.23% and 53.32% respectively; both the yield of iron (η_{Fe}) and alumina (η_{Al2O3}) in the tests were above 85.0%. The optimum reduction temperature in the tests was 1400℃.

Effects of reduction time

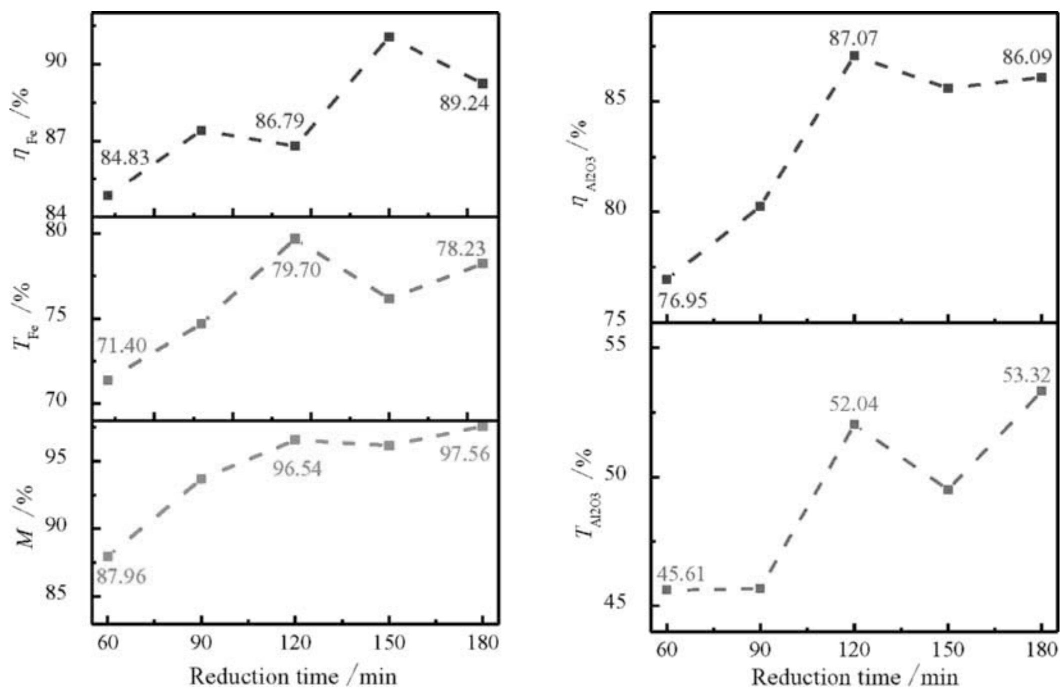
Fig. 4 describes the effects of reduction time on the process indexs. The experimental conditions includes magnetic flux intensity of 40 KA/m, reduction temperature of 1400℃, FC/O ratio of 2.0, gibbsite particle size of -2.0 mm and reduction time varying from 60 min to 180 min.

From Fig.4, it can be seen that all process index were increased with reduction time increasing. So prolonging the reduction time was beneficial for iron and alumina separation. When the reduction time was 120 min, the yield of iron (η_{Fe}) and alumina (η_{Al2O3}) in tests were 86.79% and 87.07% respectively, the content of total iron (*TFe*) in metallic iron and alumina (T_{Al2O3}) in non-metallic product were 79.70% and 52.04% respectively; both the yield of iron (η_{Fe}) and alumina (η_{Al2O3}) in the tests were above 85.0%. The appropriate reduction time in the tests was no less than 120 min.



(a) Metallic iron (b) Non-metallic product

Fig. 3 Effects of reduction temperature on the process index



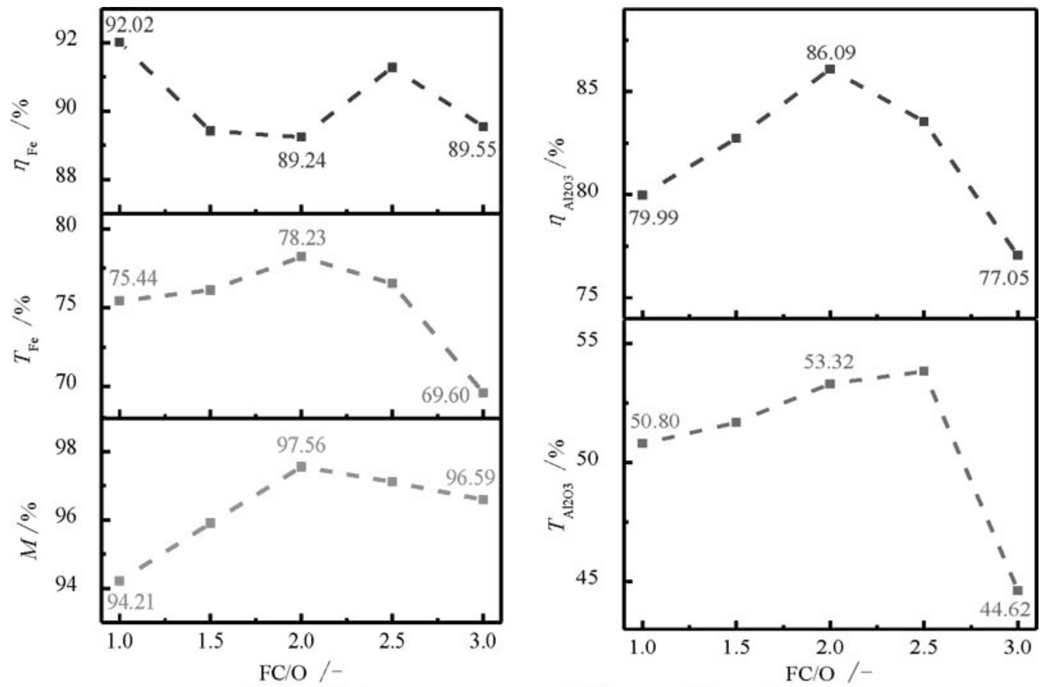
(a) Metallic iron (b) Non-metallic product

Fig. 4 Effects of reduction time on the process index

Effects of carbon ratio

The effects of carbon ratio on process index were researched with the magnetic flux intensity of 40 KA/m, reduction temperature of 1400℃, reduction time of 180 min and gibbsite particle size of -2.0 mm. The values of FC/O varied from 1.0 to 3.0. The experiment result curve is presented in Fig. 5.

It shows that the yield of iron (η_{Fe}) was above 85.0%; the yield of alumina (η_{Al2O3}) increased and then decreased with increasing carbon ratio from 1.0 to 3.0. When fixing FC/O ration at 2.0, the yield of iron (η_{Fe}) and alumina (η_{Al2O3}) in the tests were 89.24% and 86.09% respectively, the content of total iron (*TFe*) in metallic iron and alumina (T_{Al2O3}) in non-metallic product were 78.23% and 53.32 respectively. Thus, 2.0 was the optimal carbon ratio.

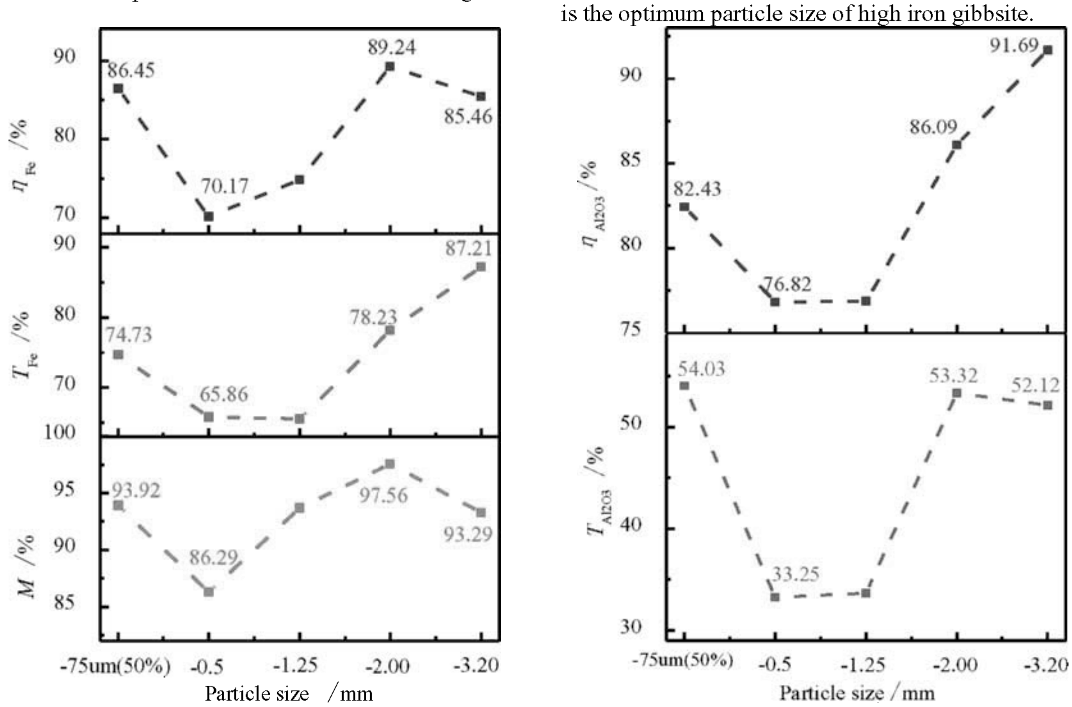


(a) Metallic iron (b) Non-metallic product

Fig. 5 Effects of carbon ratio on the process index

<u>Effects of high iron gibbsite particle size</u>

The effects of particle size of high iron gibbsite, namely, -75μm(50%), -0.5 mm, -1.25 mm, -2.0mm and -3.2mm, on process index were researched with the magnetic flux intensity of 40 KA/m, reduction temperature of 1400℃, reduction time of 180 min and carbon ratio 2.0. Experimental results are shown in Fig. 6. It shows that the yield of iron (η_{Fe}) and alumina (η_{Al2O3}) increased with increasing particle size of high iron gibbsite from -0.5 mm to -3.2 mm. When the particle size of high iron gibbsite is -75μm (50%), the yield of alumina (η_{Al2O3}) is less than 85%, so the efficiency of separating Fe-Al is bad. Thus, appropriate particle size of high iron gibbsite was from -2.0 mm to -3.2 mm, -2.0 mm is the optimum particle size of high iron gibbsite.



(a) Metallic iron (b) Non-metallic product

Fig. 6 Effects of gibbsite particle size on the process index

Conclusions

(1) The process of appropriate reduction - magnetic dressing separation requires high separation and yield ratio of iron and alumina to achieve efficient utilization of high iron gibbsite.
(2) The appropriate parameters of the new progress consist of magnetic flux intensity varying from 26.7 KA/m to 40 KA/m, reduction temperature over 1400℃, reduction time between 120 and 180 min, FC/O ratio around 2.0, high iron gibbsite particle size from -2.0 to -3.2 mm.
(3) Corresponding to the optimum process conditions (magnetic flux intensity 40 KA/m, reduction temperature 1400℃, reduction time 180 min, FC/O ratio 2.0 and gibbsite particle size -2.0 mm) the yield ratio of iron (η_{Fe}) and alumina (η_{Al2O3}) were 89.24% and 86.09% respectively.

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References

1. Wang Qiuxia, Zhang Keren, Zhao Junwei, et al, "Status, Problems and countermeasures of development and utilization of bauxite resources in China" *Conservation and Utilization of Mineral Resources*, 5(2008): 46-50.
2. Zou Jian, "Iron ore supply and demand situation analysis of China", *Metallurgy management*, 1(2009): 28-30.
3. Mu Xinhe, "Discussion on reasonable exploitation ofbauxite mineral resources in China", *Mineral Resources and Geology*, 5 (2002): 313-315.
4. Cui Pingping, Huang Zhaomin, Zhou Sulian, "Overview of bauxite resources in China", *Light Metals*, 2(2008): 6-8.
5. Zhang Jindong, Li Yintai, Bi Shiwen, "Comprehensive utilization research on high iron gibbsite in Guixian Guangxi", *Light Metals*, 12(1990): 9-12.