Light Metals 2014

ALUMINA AND BAUXITE

Non-Bayer Process

SESSION CHAIR

Hugues Tremblay
Hatch Limited
Montreal, QC, Canada

Light Metals 2014
Edited by: John Grandfield
TMS (The Minerals, Metals & Materials Society), 2014

TESTS ON COMPREHENSIVE RECOVERY OF IRON MINERALS AND BAUXITE FROM HIGH IRON DIASPORIC BAUXITE BY MEDIUM TEMPERATURE METAL-BASED ROASTING

Sichun Hu[1,2,3] Henqin Zhao[1,2] Min Guo[1,2]

1.Zhengzhou Institute of Multipurpose Utilization of Mineral Resources, CAGS, Zhengzhou, 450006, China; 2. National Engineering Research Center for Multipurpose Utilization of Nonmetallic Mineral Resources, Zhengzhou, 450006, China; 3 University of Fort Hare, Alice, 5700, South Africa

Keywords: High iron diasporic bauxite; medium temperature metal-b ased roasting; magnetic separation; lower energy consumption; comprehensive utilization

China, the largest aluminium producer, is seriously lacking of bauxite reserves. However, there are more than 200 million tons high iron diasporic bauxites cannot be properly utilized because there is no technical and economically viable technology. The medium temperature metal-based roasting technology will hopefully solve this problem. The grain growth mechanism of iron minerals, the influences of roasting temperature, roasting time, coke dosage, grinding fineness and magnetic field intensity were studied respectively. In comparison with high temperature smelting process, the energy consumption is lower. The iron minerals and bauxite in the ore are utilized effectively, and the results are desirable.

1 Introduction

There are serious bauxite reserve shortages in China because of the huge primary aluminium production capacity. The bauxite reserves ratio of China to that of the world, however, is only 2.6% but the bauxite, alumina and primary aluminium metal outputs ratios of China to world are 17.07%, 27.92% and 32.91% in 2008, respectively[1]. However, there are more than 200 million tons high iron diasporic bauxites cannot be properly utilized because there is no technical and economically viable technology. The major methods used for processing the high-iron bauxite are high intensity magnetic separation, flotation and metallurgical methods [2-4].

Bauxite with more than 15% Fe_2O_3 content is called high-iron bauxite [5]. The bauxite resources of China's are highly rich in iron and are widely distributed in the Guangxi, Henan, Shanxi and Guizhou Provinces, China. The iron oxides in bauxite occur in the form of hematite (Fe_2O_3), goethite (FeO(OH)), and aluminium goethite, which cause some problems in the Bayer Process. Firstly, the presence of very fine iron oxides usually makes the separation of the red mud from the sodium aluminate liquor slow. Flocculants are therefore added to enhance the settling rates [6], but some soluble colloidal iron particles still can escape from these operations and contaminate the final alumina product[7-8]. Secondly, when the temperature of digestion process is high (200-250℃), all of the iron except for the hematite reacts with the caustic solution, which increases the reagent consumption. A portion of aluminium would be extracted from the aluminium goethite. When the digestion temperature is low (100-150°C), the aluminium goethite remains inert resulting in the loss of aluminium in the red mud. Finally, the iron oxides complicate the treatment process of the residue, generated in the Bayer Process, which is a critical issue regarding environmental concerns and valuable metal recovery. In 2001, the disposal and management cost of red mud was about $3 per ton of alumina produced [6]. The iron oxides interfere with the titanium oxides digestion process by reacting with the acid digestion solution. In this case, the iron oxide has to be treated separately by means of magnetic separation or be sintered before the recovery of titanium oxide. This makes the procedures more complex and increases the energy consumption. Therefore, none of China's high iron bauxite has been developed and utilized, and it has become a "stagnant deposit".

The samples for this study were collected from Baode County in Shanxi Province. According to a large number of field surveys carried out and the data collected, an estimate of more than 100 million metric tons of high-iron diasporic bauxites were found in Shanxi Province. This bauxite, due to its high iron content, was not developed. There was no relevant information about the comprehensive utilization of the high iron diasporic bauxite. For the comprehensive utilization of the high iron gibbsite bauxite, the major processing methods are "the first extraction aluminium and then recycling iron", carried out at the Central South University and "the first recycling iron and then extraction aluminium" at the Northeast University [9,3]. Both of the processing techniques proved viable unreliable and expensive. Therefore, they were not applied in the industry. Because the desired results cannot be obtained by the beneficiation methods or magnetization roasting methods and the energy consumption of high temperature roasting methods (more than 1600℃) [9] is too high to be economically feasible, the medium temperature(about 1000℃) metallization roasting–magnetic separation processes was considered in this project. At this temperature, a partial liquid phase is produced in the high iron bauxite and the reaction of carbon or carbon monoxide and iron oxide will chiefly produce metal iron and partly, iron tetroxide [10]. Magnetic agglomeration can also happen due to the magnetism of the metallic iron and iron tetroxide, which will increase the particle size of the metal iron. Therefore, this can easily separate the iron and aluminium from high-iron bauxite. The energy consumption for this technique is significantly lower than that of the high temperature roasting technique. High quality iron and aluminium concentrates were obtained, and the desired result was obtained.

2 Materials and methods

2. 1 Major mineral compositions

The ores, which were tested by rock and mineral identification, were maroon in colour and massive in texture. The major mineral compositions are shown in Table 1. Their major element compositions are shown in Table 2.

Table 1: Major Mineral Compositions of Baode Bauxite (%)

composition	diaspore	kaolinite	chlorite	hematite	goethite
content	54.8	9.7	trace	22.0	8.75
composition	anatase	rutile	plagioclase	tremolite	illite
content	1.9	trace	trace	trace	trace

Table 2: Major Geochemical Compositions of Baode Bauxite

composition	Fe_2O_3	Al_2O_3	SiO_2	TiO_2	S
Content (%)	28.61	50.41	4.53	2.03	0.051
composition	K_2O	Na_2O	CaO	MgO	LOI
Content (%)	0.067	0.076	0.26	0.28	12.60

As shown in the Table 1, the diaspore and hematite contents are high. As shown in Table 3-2, the contents of Fe_2O_3 and Al_2O_3 are high; those of the K_2O, Na_2O, CaO and MgO are low and A/S is 11.13. It belongs to the type of high iron and high A/S bauxite. Based on this, to separate the Al and Fe is an important task.

2.2 Methods

The experiments were done in a box-type electric furnace, which has an excellent sealing property. The ores were firstly mixed with cokes in designed proportions, and then put into crucibles. They were then roasted in the box-type electric furnace at certain temperatures. After that, the crucibles and ores were taken out by crucible tongs and immediately put into a large volume of water for cooling. Then, it was followed by filtering, drying, grinding and magnetic separation. Lastly, the iron and aluminium concentrates were obtained. The roasting effect was assessed by the content of the magnetic iron, and the magnetic separation effect was judged by grade and recovery rate.

2.3 Flow sheet of experiments

The flow sheet of medium temperature metallization roasting and then magnetic separation is shown in Figure 1.

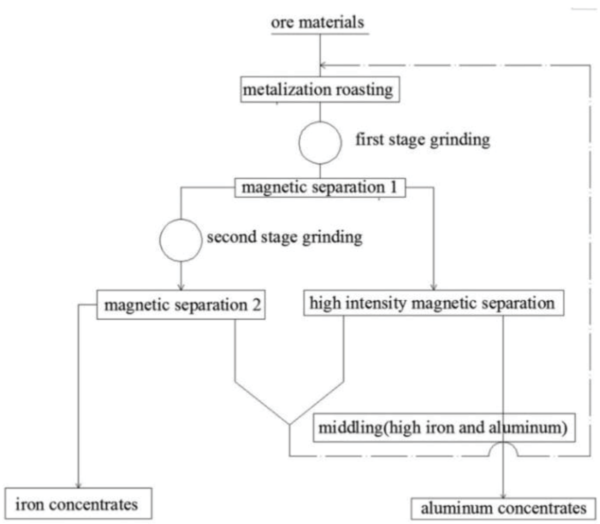

*Figure 1: The flow sheet of medium temperature metallization roasting and then magnetic separation

*: The dashed line denotes the recommendatory flow sheet but has not been done in the experiments.

As seen in Figure 1, the ore materials are processed by metalization roasting, two stages of grinding, and two stages of magnetic separation, and the iron concentrates is obtained. The ore materials are processed by metalization roasting, grinding, magnetic separation and high intensity magnetic separation, and the aluminum concentrates is obtained.

3. Results and discussion

3.1 Metallization roasting experiments

3.1.1 The results and discussion of roasting time experiments

The roasting time experiments were carried out with particle sizes of less than 2 mm, 25% of coke dosages and at a roasting temperature of 1030℃. The results are presented in Figure 2.

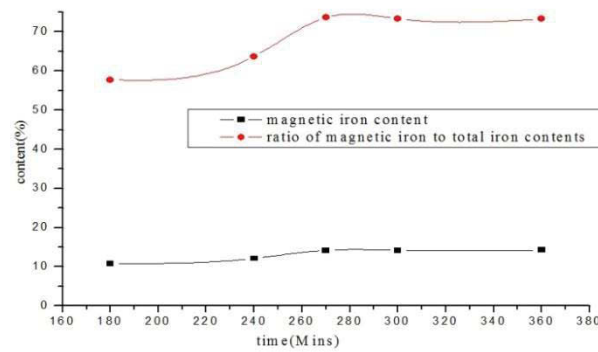

Figure 2: The results of roasting time experiments

From Figure 2, it can be seen that the magnetic iron content and MFe/TFe firstly increase and then decrease with roasting time, reaching their peaks at 270 minutes. Therefore, 270 minutes was confirmed as the optimal condition of the roasting time.

3.1.2 The results and discussion of roasting temperature experiments

The roasting temperature experiments were carried out with particle sizes of less than 2 mm, 25% of coke dosages and 270 minutes of roasting time. The results are presented in Figure 3.

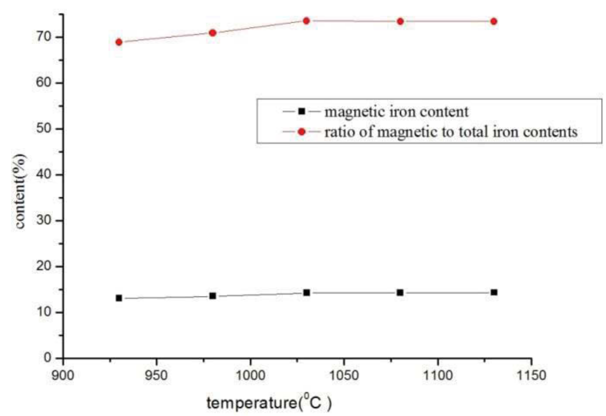

Figure 3: The results of roasting temperature experiments

From Figure 3, it can be seen that the magnetic iron content and ratio of magnetic iron to total iron contents first increase and then decrease with roasting temperature increasing and achieve peaks at 1030 ℃. Therefore, 1030 ℃ was considered as the optimum temperature.

3.2 Magnetic separation experiments

3.2.1 Magnetic field intensity experiments at the first stage

3.2.1.1 Major chemical compositions of feed materials The feed materials were acquired by the experiments under the conditions of 25% of the coke dosages, 270 minutes roasting time and 1030℃ roasting temperature. The compositions of the roasted samples are shown in Table 3.

Table 3: Major Compositions of Roasted Samples (%)

composition	TFe	MFe	Al_2O_3	SiO_2	C
content	19.31	14.21	50.86	5.99	14.85

3.2.1.2 Results and discussion of magnetic field intensity experiments at the first stage The feed materials, which are obtained from roasting experiments with 25% of coke dosages, 270 minutes of roasting time and 1030℃ of roasting temperature, contain Fe 19.31%, magnetic Fe 14.21% and Al_2O_3 50.86%. The magnetic field intensity experiments were done under the condition of 70% less than 75 µm grinding fineness. The experimental results are shown in the Figure 4.

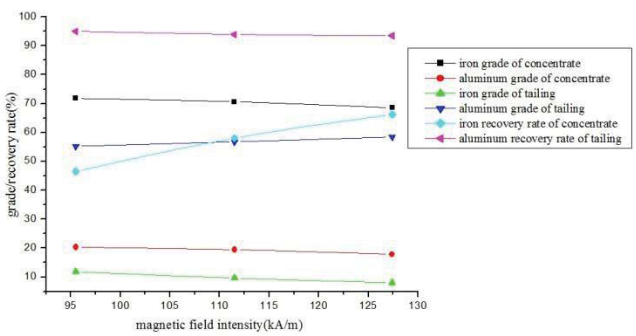

Figure 4: The results of magnetic field intensity experiments at the first stage

As seen in Figure 4, the iron and alumina grade of the concentrate (magnetic material), the iron grade of the tailings (non-magnetic material), and the aluminium recovery rate of the tailings (non-magnetic material) decrease with an increase in magnetic field intensity, while the aluminium grade of the tailings (non-magnetic material) and the iron recovery rate of the concentrate (magnetic material) increase. Based on the above analysis, 127.4kA/m was determined as the optimum magnetic field intensity at the first stage. In such conditions, the iron recovery rate can be improved as much as possible on the basis that a certain grade is guaranteed.

3.2.1.3 Results and discussion of grinding fineness experiments at the first stage The feed materials, which are obtained from roasting experiments with 25% of coke dosages, 270 minutes of roasting time, and a roasting temperature of 1030℃, contain Fe 19.31%, magnetic Fe 14.21% and Al_2O_3 50.86%. The grinding fineness experiments were done under the condition of 127.4kA/m. The experimental results are shown in Figure 5.

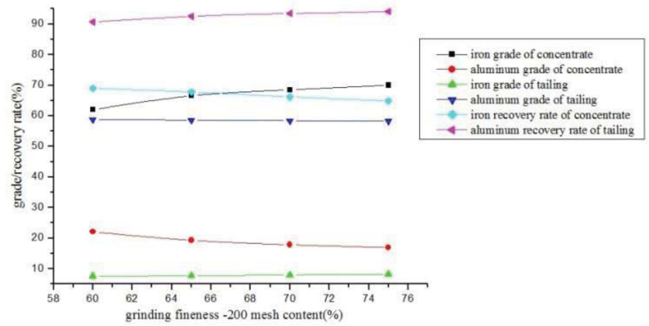

Figure 5: Grinding fineness experiments at the first stage

As shown Figure 5, the iron grades of the concentrate (magnetic material) and the tailings (non-magnetic material), and the aluminium recovery rate of the tailings (non-magnetic material) increase with an increase in less than 75 µm of grinding fineness, while the aluminium grades of the concentrate (magnetic material) and the tailings (none-magnetic material) and the iron recovery rate of the concentrate (magnetic material) decrease. Based on the above analysis, the grade and the recovery rate are considered comprehensively and 70% of less than 75 µm of grinding fineness was determined as the optimum grinding fineness.

3.2.1.4 Magnetic field intensity experiments at the second stage The feed materials, which collected as the concentrate (magnetic material) at the first stage of magnetic separation, contain Fe 68.53%, magnetic Fe 63.15% and Al_2O_3 17.86% at a production rate of 18.66%. The flow sheet is presented in Figure 3-34 above. The experiments were done under conditions of 90% -75 µm of grinding fineness and different magnetic field intensity, and the results are shown in Figure 6.

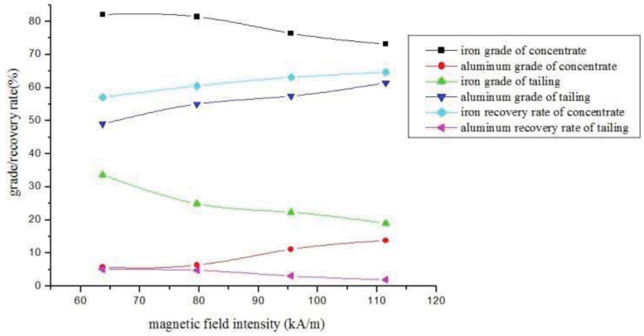

Figure 6: Magnetic field intensity experiments at the second stage

As seen in Figure 6, the iron grade of the concentrate (magnetic material), the iron grade of the tailings (non-magnetic material) and the aluminium recovery rate of the tailings (non-magnetic material) decrease with an increase in magnetic field intensity, while the aluminium grades of the concentrate (magnetic material) and the tailings (non-magnetic material), and the iron recovery rate of the concentrate (magnetic material) increase. Based on the above analysis, the grade and recovery rate are considered comprehensively and 79.62kA/m was determined as the optimum magnetic field intensity at the second stage of magnetic separation.

3.2.1.7 Major chemical compositions of the final iron and aluminium concentrates The final iron concentrate, which contains Fe 81.45% and Al_2O_3 6.36% at a production rate of 14.25% with 60.53% of iron recovery rate, and the final aluminium concentrate, which contains Al_2O_3 60.56%, Fe 5.45% at a production rate of 61.82% with 73.62% of aluminium recovery rate, were obtained. Because the middling is a mixture of the tailings (non-magnetic material), and the continuous tests were not carried out, the middling samples could not be collected and not analyzed. On the other hand, the middling samples are not very important and the middling compositions can be estimated easily according to the interrelationships of the contents, production and recovery rates. The middling contains Al_2O_3 52.28% and Fe 17.78% at a production rate of 23.93% with 24.60% of aluminium recovery rate and 22.03% of iron recovery rate through calculation according to the interrelationships of the contents, production and recovery rates. The major chemical compositions of the final iron and aluminium concentrates are presented in Tables 4 and 5 and Figures 7 and 8.

Table 4: Major Chemical Compositions of the Final Iron Concentrate (%)

composition	TFe	Al_2O_3	SiO_2	TiO_2
content	81.45	6.36	3.65	0.71
composition	K_2O	Na_2O	CaO	MgO
content	0.061	0.26	1.43	0.46

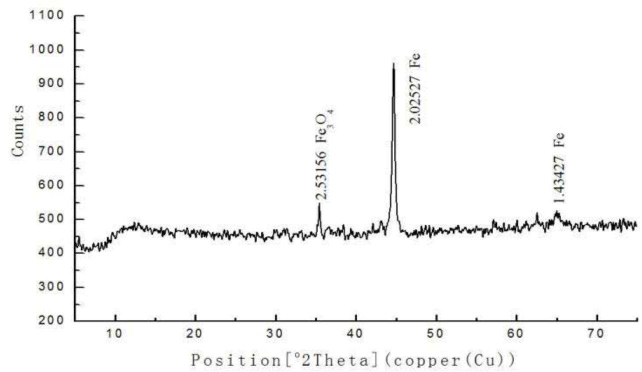

Figure 7: XRD pattern of the final iron concentrate

Table 5: Major Chemical Compositions of the Final Aluminium Concentrate (%)

composition	TFe	Al_2O_3	SiO_2	TiO_2	S	P
content	5.45	60.56	6.92	2.45	0.046	0.038
composition	K_2O	Na_2O	CaO	MgO	C	LOI
content	0.05	0.048	0.32	0.36	19.85	16.89

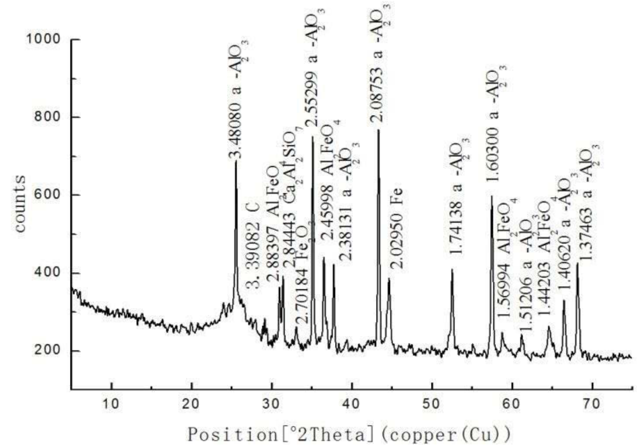

Figure 8: XRD pattern of the final aluminium concentrate

From Tables 4 and 5 and Figures 7 and 8, it can be seen that the final iron concentrate contains only Al_2O_3 6.36% and Fe 81.45% and that it is composed mostly of metal iron and little magnetite. The final aluminium concentrate contains Al_2O_3 60.56%, Fe 5.45% and *C* 19.85% and it is chiefly composed of α-Al_2O_3. Because of test conditions restriction, excessive cokes (about 25%) were added in order to make sure it had enough reduction atmospheres. The excessive cokes were mingled into the aluminium concentrate, which greatly reduced the quality of the aluminium concentrate. To avoid this disadvantage, the processing method of gas reduction metallization roasting was adopted at temperature around 1000℃. By this processing method, high quality aluminium and iron concentrates will be obtained.

4 Conclusions

Medium temperature metallization roasting, two stages of grinding, one stage of high intensity magnetic separation, and two stages of low intensity magnetic separation were carried out. Then, the final iron concentrate, which contains Fe 81.45% and Al_2O_3 6.36% at a production rate of 14.25% with 60.53% of iron recovery rate, and aluminium concentrate, which contains Al_2O_3 60.56%, Fe 5.45% at a production rate of 61.82% with 73.62% of aluminium recovery rate, were obtained. The final iron concentrate and the final aluminium concentrate were of high quality except for the high carbon(C) content of the final aluminium concentrate due to the restriction of test conditions. However, less than 5% of the coke dosages may be enough under industrial production conditions in reference to the similar iron ore roasting cases, so it is not a great problem. Finally, the desired effects were achieved.

References

[1] Hu, S.C., *Investigation and Laboratory Tests of Sub-Economic Aluminium Resources in China.* (PhD dissertation, University of Fort Hare, Alice East Cape South Africa, 2012), 12.

[2] Wei, D.S., Study on all-around utilization of high iron-aluminium ore. *Nonferrous metals (Beneficiation),* 6 (2008), 14-18.

[3] Zhu, Z. et al., Sintering properties of high iron gibbsite-type bauxite ores. *The Chinese Journal of Nonferrous Metals,* 17(8), (2007), 1360-1366.

[4] Li, G. et al., Mineralogy and separation of aluminium and iron from high iron bauxite. *J. Cent. South Univ. (Science and technology), 37*(2), (2006), 235-240.

[5] Hu, S. C. et al., Tests onmedium temperaturemetal- based roasting- magnetic separation of high ferrous bauxite. *Light metals,* 9 (2010), 6-10.

[6] Li, Y., A study of iron mineral transformation to reduce red mud tailings. Waste Management, 21 (2001), 525-534.

[7] Hind, A. R., Bhargara, S. K. & Grocott, S. C., The surface chemistry of Bayer process solids: a review. *Colloids and Surfaces A: Physicochemical and Engineering Aspects,* 146(1999), 359-374.

[8] Ostap, S., Effect of bauxite on its processing characteristics. *Bauxite, Leonard Jacob, Jr., (editor)*, (1984), 651-671.

[9] Tong, Z., *Research on Comprehensive Utilization of Iron-bearing Bauxite in Guigang Guangxi.* (PhD dissertation, North East University, ShenYang, China, 2005), 60..

[10] Fu, J., Jiang, T. & Zhu, D., Study on sintering and pelletizing process. Changsha: *Central South University of Technology Press*, (1996), 45.