

BR04 - Experimental Study on Mineral Phase Transformation - Low Intensity Magnetic Separation of High Iron Red Mud of Guinea Bauxite

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Abstract

The total Fe content (TFe) of a bauxite residue (red mud) obtained from Guinea bauxite by low temperature digestion is 39.45 %, which was found mainly in the form of alumogothite and hematite. Alumogothite accounts for 56.59 % of iron minerals. It was difficult to obtain quality iron concentrate with TFe content greater than 56 % by direct magnetic separation process. In order to develop an effective recovery of iron minerals from red mud, systematic tests of iron mineral recovery were carried out by adopting the process of “preconcentration and quality improvement - mineral phase transformation - low intensity magnetic separation” in this paper. The results showed that the red mud preconcentration and quality improvement technology could achieve the enrichment of iron and reduction of the amount of red mud. The preconcentrate after the mineral phase transformation and weak magnetic separation of iron, the magnetization of low intensity magnetic iron containing minerals reaches more than 80 %, the iron concentrate yield was 34.41 %, and the TFe content was 56.40 %, which was more than 4 % higher than the current imported red mud iron concentrate. This promises a feasible technical path for large-scale production of high iron red mud based on Guinea bauxite and provides technical support for an economic and efficient utilization of a Guinea bauxite.

Keywords: Guinea bauxite, High iron red mud, Alumogothite, Preconcentration and quality improvement, Mineral phase transformation.

1. Introduction

Red mud has been the main waste residue obtained during the production of alumina by the Bayer process. It has been difficult to utilize due to its strong alkalinity and complex phase composition. Therefore, it has been mostly stacked for disposal. According to statistics, every 1 ton of alumina produced is associated with 1-2 tons of red mud [1,2]. At present, the global stock of red mud exceeds 4 billion tons (as dry matter) and is increasing at a rate of 180 million tons per year [3-5]. The conventional red mud storage is associated with the risk of pollution of water, soil and the atmosphere, and has the potential of safety hazards. This comprises an urgent problem to be solved for the high-quality development of the alumina industry [6].

According to the statistics of China Nonferrous Metals Industry Association, the amount of red mud produced in China in 2022 was 105 million tons, and the amount of red mud by using Guinea bauxite to produce alumina was 24 million tons per year, accounting for more than 20 % of the amount of red mud produced. In 2022, the comprehensive utilization of red mud in China was 8 million tons, and the comprehensive utilization rate was only about 7.5 %. The TFe content in red

mud obtained from bauxite originated from Guinea is relatively high, which can generally reach more than 35 %. With the consumption of high-quality iron ore resources in China, red mud can be considered as a secondary resource for comprehensive recovery and utilization of iron minerals [7-9]. The proportion of alumogothite in iron-bearing minerals in the red mud from digestion of Guinea bauxite is more than 50 %. Due to the weak magnetism of alumogothite, the grade of iron-bearing minerals cannot be increased to more than 56 % TFe by conventional magnetic separation, gravity separation and other conventional separation methods. These products cannot meet the quality requirements of iron concentrates. At the same time, due to the high viscosity of red mud, the high moisture of filter cake and the difficulty of dewatering, the energy consumption of drying and roasting was relatively high, so it was necessary to develop innovative technologies for the comprehensive recovery and utilization of iron minerals.

This paper mainly focuses on the problems of high-iron red mud of Guinea bauxite, such as difficult dewatering, high energy consumption of drying and roasting, high content of alumogothite, and the difficulty in obtaining quality iron concentrate by conventional magnetic separation. The continuous experimental study of red mud iron separation was carried out to provide a technology for the large-scale production of high-iron red mud concentrate.

2. Tests

2.1 Test Material

The test material was high-iron red mud produced by an alumina enterprise in Guangxi using Guinea bauxite. The results of chemical composition analysis and mineralogical phase analysis of the sample are shown in Table 1 and Table 2.

Table 1. The chemical composition of high-iron red mud.

Element	Al ₂ O ₃	SiO ₂	Fe ₂ O ₃	TFe	TiO ₂	K ₂ O	Na ₂ O	CaO	MgO
Content, %	16.8	5.49	56.35	39.45	5.52	0.08	2.19	1.5	0.06

Table 2. The mineralogical phase analysis of high-iron red mud.

Mineral	Alumogothite	Hematite	Quartz	Sodium hydrate aluminosilicate	
Content, %	36.5	28.0	2.2	9.9	
Mineral	Anatase	Rutile	Boehmite	Gibbsite	Calcite
Content, %	1.2	4.3	8.5	3.0	2.6

It can be seen from the analytical results of Table 1 and Table 2 that the iron content in the red mud was high, and the TFe content was 39.45 %. The iron minerals mainly exist in the form of alumogothite and hematite, among which alumogothite accounts for 56.59 % of the iron-bearing minerals, and it was difficult to recover the iron minerals by high intensity magnetic separation process.

2.2 Technological Process

The continuous test process block flow diagram of iron separation of high-iron red mud of Guinea bauxite is shown in Figure 1.

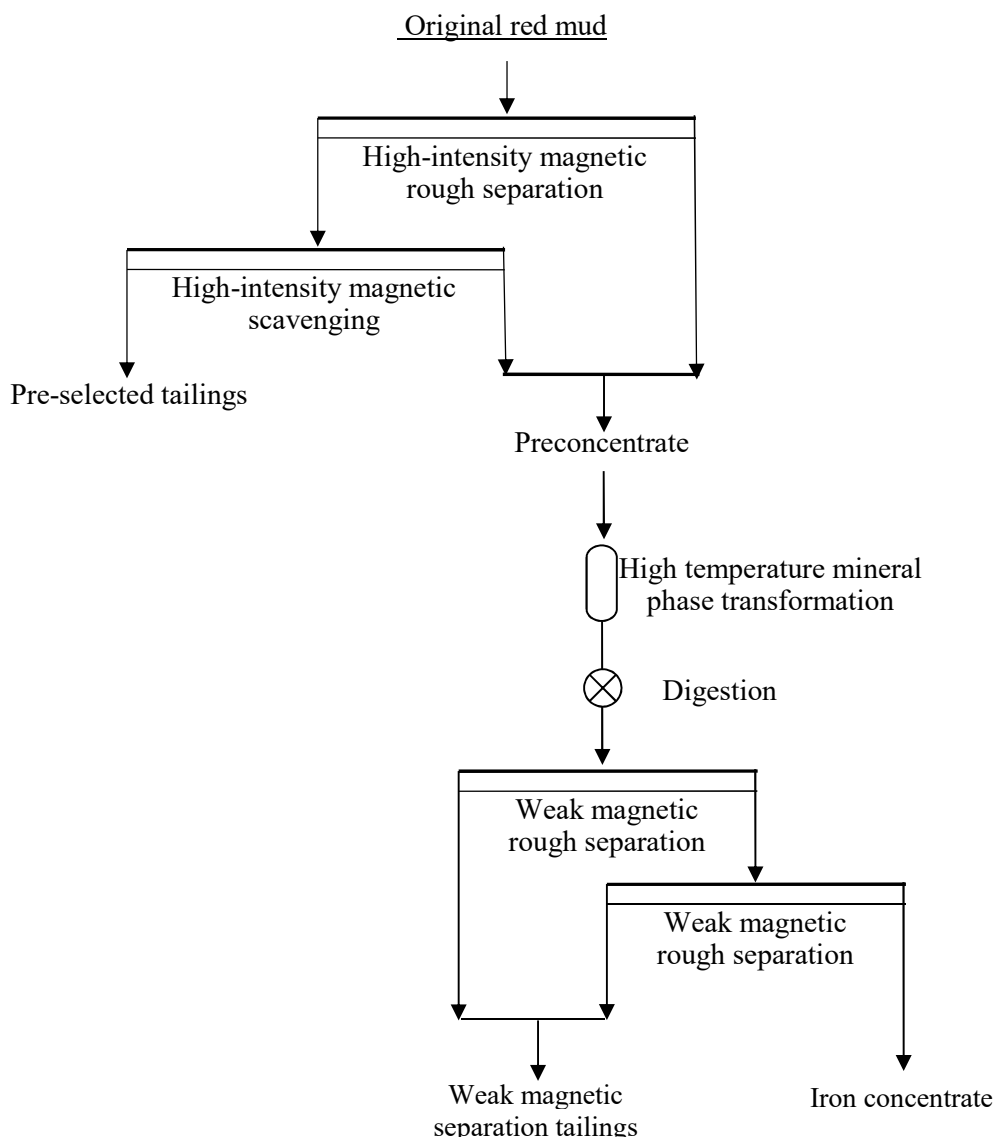


Figure 1. Block flow diagram of continuous test of iron separation from high-iron red mud of a Guinea bauxite.

It can be seen from Figure 1 that the red mud of a Guinea bauxite was first preconcentrated by a rough high intensity magnetic separation and a high intensity magnetic scavenging, and preconcentrate and preconcentration tailings were obtained. After dewatering, drying and crushing, the preconcentrate was delivered into the high-temperature mineral transformation stage by suspension roaster. The transformed ore then enters the low-intensity magnetic separator after grinding and digestion. After one rough and one cleaning low-intensity magnetic separation, low-intensity magnetic separation iron concentrate and the low-intensity magnetic separation tailings were obtained. The iron concentrate can serve as quality raw materials for the iron and steel industry.

3. Results and Discussion

3.1 Continuous Experimental Study on Pre-concentration and Quality Improvement

Based on the study of the properties high iron red mud of Guinea bauxite, in order to recover the iron-containing minerals in red mud, a SLOn-100 periodic pulsating high-gradient magnetic separator was used to carry out the laboratory high-intensity magnetic preconcentration tests. The test results of different magnetic field strength conditions under the process of one rough and one cleaning, one rough and one scavenging step are shown in Figure 2 and Figure 3.

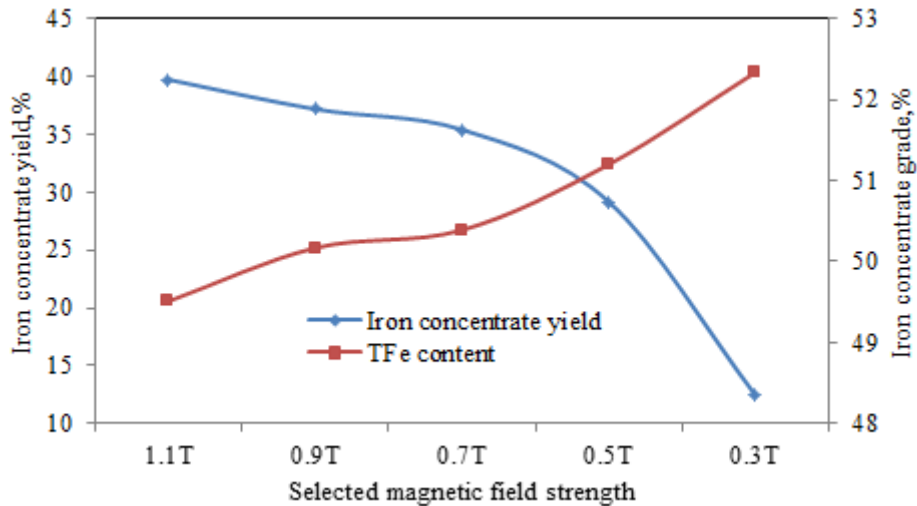


Figure 2. Test results of a rough and a cleaning conditions of high iron red mud of a Guinea bauxite.

It can be seen on Figure 2 that the grade of the iron concentrate was about 50 % TFe by one rough and one cleaning separation. By reducing the magnetic field intensity of cleaning, the grade of iron concentrate increases slightly, but the yield decreases significantly. When the TFe content of iron concentrate was 52.34 %, the yield was only 12.43 %, indicating that it was difficult to obtain iron concentrate with TFe content greater than 56 % by direct magnetic separation.

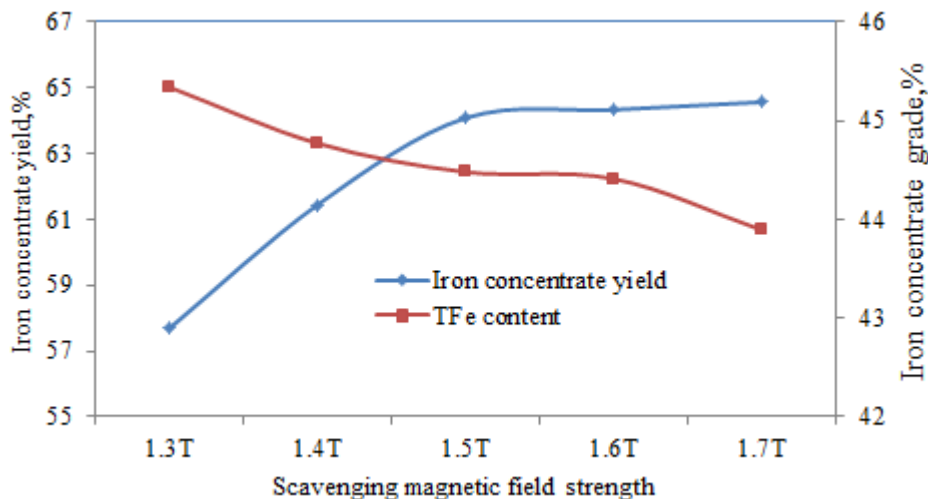


Figure 3. Test results of a rough and a scavenging conditions of high iron red mud of a Guinea bauxite.

It can be seen from Figure 3 that through a rough and a scavenging, with the increase of scavenging field strength the yield of pre-concentrate increases and the grade decreases continuously. Considering the grade and recovery rate of iron concentrate, when the field strength

of the rough stage was 1.3 T and the scavenging field strength was 1.5 T, the yield of pre-concentrate was 64.08 % and the TFe content was 44.48 %.

3.2 Continuous Tests of High Temperature Mineral Phase Transformation - Low Intensity Magnetic Separation of Iron

The effects of the mineral phase transformation temperature, CO concentration and the ore amount on the recovery of iron minerals in a red mud from Guinea bauxite were investigated by bench scale tests.

3.2.1 Effect of Mineral Phase Transformation Temperature on the Separation Index

In the process of high temperature mineral phase transformation, temperature plays a vital role. Therefore, when the treatment capacity was 100 kg/h and the CO concentration was 1.5 %, the tests of different temperature conditions were carried out, and the red mud after the mineral phase transformation was ground to 90 % of $- 0.074$ mm for low intensity magnetic separation of iron. The test results are shown in Figure 4.

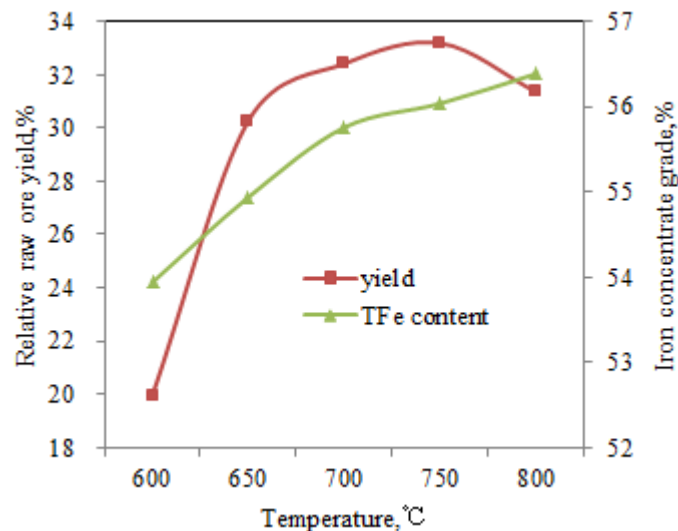


Figure 4. Test results of high temperatures of mineral phase transformation.

It can be seen from Figure 4 that the yield of iron concentrate in low-intensity magnetic separation increases first and then decreases with the increase of the mineral phase transformation temperature, while the TFe content increases with the increase of the same. This was because the roasting efficiency was low when the temperature was low, and the increase of temperature was conducive to the reduction of alumogothite and hematite to magnetite. When the roasting temperature exceeds 750 °C, the phenomenon of over-reduction occurs, resulting in the magnetic decline of the roasted ore. Considering the yield of iron concentrate, TFe content and production cost, the optimum phase transformation temperature was determined to be 750 °C. Under this condition, the yield of iron concentrate was 33.19 % and the TFe content was 56.04 %.

3.2.2 Effect of CO concentration on the Separation Index

Under the condition of 100 kg/h treatment capacity and 750 °C mineral phase transformation temperature, tests of different CO concentrations were carried out, and the red mud after the mineral phase transformation was ground to 90 % of $- 0.074$ mm for low intensity magnetic separation of iron. The test results are shown in Figure 5.

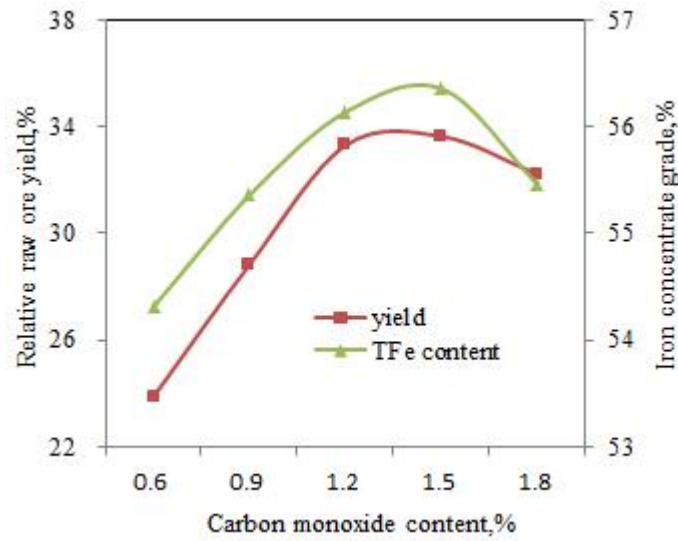


Figure 5. Test results of different CO concentrations.

It can be seen from Figure 5 that with the continuous increase of CO concentration, the TFe grade and the iron recovery rate of low-intensity magnetic separation of iron concentrate increase first and then decrease. The analysis shows that too low CO concentration leads to an insufficient conversion of aluminosilicate and hematite to magnetite. If the concentration of CO is too high, excess CO continues to react with magnetite to form weakly magnetic FeO. Therefore, the optimum concentration of CO was determined to be 1.5 %. At this condition, the yield of iron concentrate was 33.65 % and the content of TFe was 56.36 %.

3.2.3 Effect of the Treatment Capacity on the Separation Index

At the mineral phase transformation temperature of 750 °C and CO concentration of 1.5 %, tests at different treatment capacities were carried out. The red muds after the mineral phase transformation were ground to 90 % of - 0.074 mm for low intensity magnetic separation of iron. The test results are shown in Figure 6.

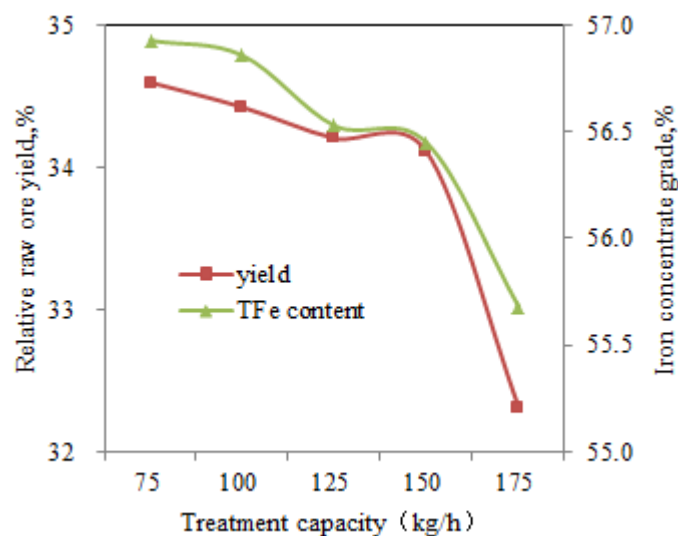


Figure 6. Test results of treatment capacity condition.

It can be seen on the Figure 6 that with the continuous increase of the treatment capacity, the yield and TFe content of the low-intensity magnetic separation of the iron concentrate continuously reduced, mainly because when the treatment capacity was too large, the reaction of the reduction of alumogothite and hematite to magnetite was not sufficient, which makes the separation worse. Considering the iron concentrate yield and the production cost of the low intensity magnetic separation, the treatment capacity was determined to be 150 kg/h. Under this condition, the yield of iron concentrate was 34.11 % and the TFe content was 56.45 %.

3.2.3 Effect of Grinding Fineness on Separation Index

The red mud obtained at the conditions of 150 kg/h of treatment capacity, 750 °C of mineral phase conversion temperature and 1.5 % of CO concentration was tested at different grinding fineness conditions. The test results are shown in Figure 7.

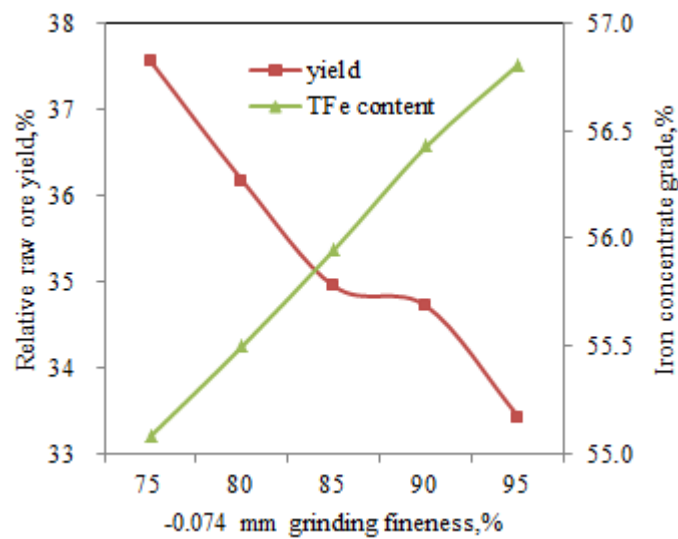


Figure 7. Test results of grinding fineness condition.

It can be seen in Figure 7 that the yield of the low-intensity magnetic iron concentrate gradually decreases with the increase of grinding fineness, while the TFe content gradually increases with the same. Therefore, considering the iron concentrate yield and the grinding energy consumption of the low intensity magnetic separation, the grinding fineness was determined to be - 0.074 mm accounting for 90 %. At this condition, the iron concentrate yield was 34.71 % and the TFe content was 56.43 %.

3.3 Continuous Test of Red Mud of Guinea Bauxite for Preconcentration and Quality Improvement - Mineral Phase Transformation - Low Intensity Magnetic Separation

3.3.1 Stable Operation Average Process

According to the results of the previous tests, when the treatment capacity was 150 kg/h, the mineral phase conversion temperature was 750 °C, the CO concentration was 1.5 %, and the grinding fineness was 90 % of - 0.074 mm, the process block flow diagram shown in Figure 1 were used to carry out “preconcentration and quality improvement - mineral phase transformation - low intensity magnetic separation” stable operation continuous test with the red mud from Guinea bauxite. The test results are shown in Table 3.

Table 3. Average indexes of each product in continuous test of iron separation from red mud of a Guinea bauxite.

Test step	Product Name	Yield, %	TFe, %	Recovery rate,/%
preconcentration and quality improvement	Original red mud	100.00	40.18	100.00
	Pre-selected tailings	37.54	32.05	29.94
	Preconcentrate	62.46	45.07	70.06
mineral phase transformation	Ignition loss	6.53	/	/
	Red mud after conversion	55.93	50.33	70.06
low intensity magnetic separation	Weak magnetic separation of iron concentrate	34.41	56.40	48.31
	Weak magnetic separation tailings	21.52	40.62	21.75

It can be seen from Table 3 that for the red mud of a Guinea bauxite with TFe content of 40.18 %, the average yield of preconcentrate was 62.46 % and its average TFe content was 45.07 %. The preconcentrate was submitted to a mineral phase transformation and a weak magnetic separation of iron. A large portion of the weak magnetic iron minerals were transformed into strong magnetic iron minerals. The overall iron concentrate yield was 34.41 %, and the TFe content was 56.40 %, which was more than 4 % higher than the current imported red mud based iron concentrate.

3.3.2 Product Analysis

In order to find out the effect of the high temperature mineral phase transformation of preconcentrate, the iron mineralogical phase analysis of red mud after the mineral phase transformation was carried out. The analysis results are shown in Table 4.

Table 4. Analytical results of iron phases in red mud after high temperature mineral phase transformation.

Iron mineral phase	Content,%	Distribution,%
Iron in magnetite	24.96	49.01
Iron in martite	16.88	33.14
Iron in hematite and alumogothite	8.03	15.77
Iron in carbonates	0.1	0.20
Iron in free ferrous iron	0.73	1.43
Iron in sulfides	0.03	0.06
Iron in iron silicate	0.2	0.39
mFe	42.23	82.92
TFe	50.93	100

It can be seen from Table 4 that after the preconcentrate was submitted to heat treatment, the weakly magnetic alumogothite and hematite were mainly converted into magnetite and martite. The distribution of magnetic iron (mFe) was 82.92 %, and the magnetization effect was better.

4. Conclusions

The content of TFe in the red mud obtained by a low-temperature digestion of a bauxite in Guinea was 39.45 %, and the iron minerals mainly were found in the form of alumogothite and hematite. The alumogothite accounts for 56.59 % of the iron minerals, and it was difficult to recover the iron minerals by high intensity magnetic separation process.

The magnetic susceptibility of weak magnetic iron-bearing minerals was more than 80 % by using high temperature mineral phase transformation of red mud, which solves the technical problem that it cannot be obtained quality iron concentrate by conventional magnetic separation technology from red mud of a Guinea bauxite. Through the continuous test of iron separation from red mud, the yield of the iron concentrate was 34.41 %, and the content of TFe was 56.40 %. This has proven a technical path for the large-scale production of high-iron red mud concentrate from Guinea bauxite and has provided technical support for the economical and efficient utilization of Guinea 's bauxite.

Although the mineral phase conversion technology presented in this paper has the advantages of short roasting time and low CO concentration, but its roasting temperature was high, so it needs to be further studied in terms of reducing the roasting energy consumption and the production cost.

5. Acknowledgement

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6. References

1. Liu Xiao et al., Recovery process of iron from high-iron red mud through suspension magnetization roasting-low intensity magnetic separation technology, [J]. *Journal of Northeastern University (Natural Science)*. 2021(3): 414-421.
2. Wang, Y, X et al., Recovery of alkali and alumina from bauxite residue (red mud) and complete reuse of the treated residue, [J]. *Journal of Cleaner Production*, 2018,188:456-465.
3. Archambo M, Kawatra S K, Red mud: fundamentals and new avenues for utilization, [J]. *Mineral Processing and Extractive Metallurgy Review*, 2020(2): 1-24.
4. Yuan S et al., A semi-industrial experiment of suspension magnetization roasting technology for separation of iron minerals from red mud, [J]. *Journal of Hazardous Material*, 2020,394:122579.
5. Lu G Z et al., Utilization of Bayer red mud by a calcification-carbonation method using calcium aluminate hydrate as a calcium source, [J]. *Hydrometallurgy*, 2019,188:248-255.
6. Nan Xiangli et al., Main categories of red mud and its environmental impacts. [J]. *The Chinese Journal of Process Engineering*, 2009,9(s1) 459-464.
7. Sun Yongfeng et al., Technology for recovering iron from red mud by Bayer process. [J]. *METAL MINE*, 2009(9):176-178.
8. Liu Shuren et al., Study of recovering iron from Bayer red mud, [J]. *Light Metals*, 2014(2):14-17.
9. Zhang Shumin et al., Recovery of iron minerals from red mud by gas reduction roasting and low intensity magnetic separation [J]. *METAL MINE*, 2018(8):179-182.