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Effect of chamosite on Bayer process of special diasporic bauxite with high silica

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Abstract: Technological investigations were carried out based on the Bayer process. Predesilication characteristic of the bauxite, the effects of digestion temperature and retention time, concentration of Na_2O and amount of CaO addition on Al_2O_3 digestion efficiency in Bayer process, the settling characteristics of the red mud were determined. The bauxite in the northern region of China is diasporic type with high silica (in 6-15% SiO_2). The main silica minerals in the bauxite are kaolinite and chamosite. The presence of high silica causes high bound-soda losses in the red mud in the Bayer process, but a part of silica content in the bauxite was in the form of chamosite, the bound-soda losses can be greatly reduced with chamosite mineral by using Bayer process. Therefore, it is necessary to study digestion characteristics of the special diasporic bauxite and settling separation properties of the red mud by Bayer process.

Keywords: chamosite, settling separation, Bayer process, diasporic bauxite

1. Chemical composition of the bauxite samples

After crushing and mixing of each sample, their chemical composition was analyzed. The results are listed in Table I. It is obvious that only a small number of bauxite samples contained low SiO_2 content less than 7%, so it is not likely to produce alumina with it through Bayer process. But fortunately, part of silica in this bauxite exists as chamosite, and which does not react with caustic to form sodium-aluminum hydrosilicates causing soda losses in Bayer digestion process. Therefore, the possibility of using this type of bauxite as raw material to produce alumina by Bayer process still exists. We divided the bauxite samples into 2 groups (high and low silica content groups), mixed the samples into 6 mixed samples and ground them to pass 100 mesh. The mixed samples were used for predesilication, digestion and red mud settling tests by Bayer process.

Table I Chemical Composition of the bauxite Samples.

Sample Number	Composition(Wt %)				
	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	Loss on Ignition
m-1	10.2	52.9	21.4	3.5	10.9
m-2	15.1	48.9	21.0	3.0	11.3
m-3	9.5	51.8	20.9	3.9	12.0
m-4	13.9	44.9	21.9	3.6	11.8
m-5	6.4	49.2	26.4	5.4	11.6
m-6	16.3	49.0	14.9	5.7	11.9

2. Mineral composition and structural characteristics of the bauxite samples

The mineral composition and structural characteristics of the bauxite samples were determined by X-ray diffractometry, Infrared Spectrophotometry, Polarization Microscopy and Scanning Electron Microscopy analyses.

Figures 1 and 2. illustrate the x-ray diffraction patterns and IR absorption spectra for the six bauxites, respectively. Alumina is present primarily as diaspore. Silica is present mainly as kaolinite and chamosite(as Figures 3 and 4) with trace amounts as illite. Hematite is the main iron mineral (wt % 19.0 consistent), but limonite, siderite exist in small quantities. Rutile and anatase are the main titanium minerals. There are some other minerals such as calcite and zircon in the bauxite.

The distribution of alumina and silica in different minerals was calculated on the basis of quantitative analysis of main minerals in various bauxite samples and the results are listed in Table II.

Further investigation on structural characteristics of the bauxite was carried out. It was found that the bauxite did not belong to bedded ore deposit and the texture is rather complicated. The main textural characteristics of the bauxite are crystal, microlitc and aphanitic texture.

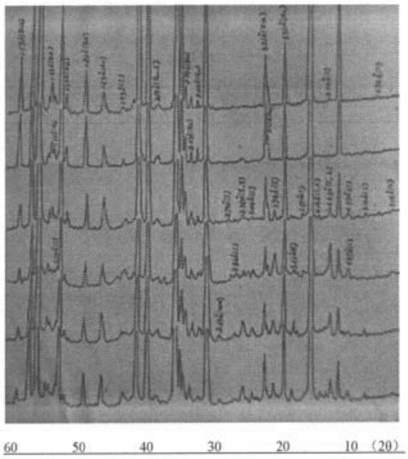

Figure 1 X-ray diffraction pattern of the bauxite samples
Legends: a to f from top to bottom

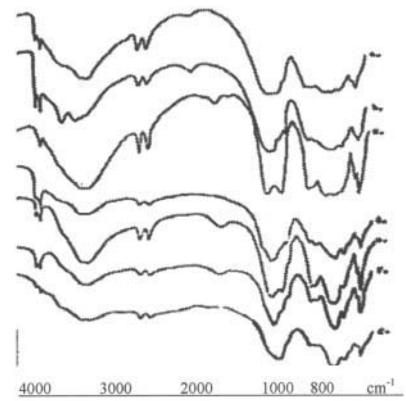

Figure 2 IR absorption spectrum of the bauxite samples
Legends: a. m-1, b. m-2, c. m-3, d. m-4, e. m-5, f. m-6

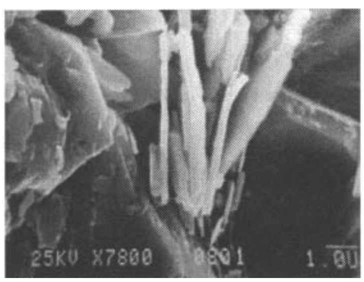

Figure 3 chamosite crystal in bauxiteSEM

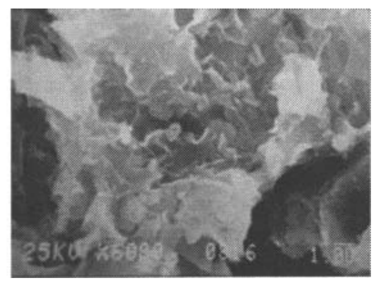

Figure 4 kaolinite crystal in bauxiteSEM

Table II. The distribution of the main components of bauxite in individual mineral phases

Components	Composition(Wt %)					
	m-5	m-6	m-3	m-4	m-1	m-2
Al_2O_3 in diaspore	44.2	33.7	43.9	35.3	42.2	27.7
Al_2O_3 in kaolinite	4.0	6.4	1.7	10.0	4.8	10.4
Al_2O_3in chamosite	2.1	2.8	1.8	2.2	3.4	1.6
SiO_2 in kaolinite	3.3	4.8	2.6	2.2	3.7	1.5
SiO_2 in chamosite	4.6	7.6	2.0	11.9	5.7	12.3
Fe_2O_3 in hematite	19.5	18.9	18.7	20.5	24.7	13.5

3. Predesilication tests

The purpose of predesilication tests was to determine the extent of reaction between SiO_2 of the bauxite and alkaline liquor to form sodium-aluminum-hydrosilicate in slurry tanks. Raw materials of the tests were:

mixed bauxite samples,

containing 90.1% CaO.

The Digestion liquor was prepared from chemically pure NaOH, Na_2CO_3, $Al(OH)_3$ and de-ion water.

The results of predesilication efficiency are listed in Table III.

The results of predesilication tests showed: 1) when the concentration of Na_2O_T in liquor is in the range from 150 to 190 g/L, the rate of sodium-aluminum-hydrosilicate formation was not significantly influenced by the concentration of

Table III. The results of predesilication tests of the bauxite samples

Sample Number	Amount of Bauxite (g/L)	Amount of Lime (g/L)	Composition of Digestion liquor (g/L)			Temperature of Reaction (°C)	Retention Time (hr.)	Predesilication Efficiency (%)
			Na_2O_T	Al_2O_3	Na_2O_K			
m-1	181.7	12.9	162.1	67.5	139.8	98	2	53.3
m-2	205.1	19.0	192.3	73.3	159.9	98	8	57.3
m-3	149.3	10.2	162.0	67.4	139.4	98	2	25.5
m-4	149.1	10.5	162.2	67.3	139.3	98	8	43.6
m-5	192.5	12.4	162.3	67.5	139.6	98	2	25.3
m-6	192.7	12.5	161.9	67.2	139.5	98	8	30.5

Legends: Na_2O_T=Na_2O_K+Na_2O_C, the same as in following tables

Na_2O_k; 2) Predesilication efficiencies of these six bauxite samples were different due to their percentage differences in chamosite contents.

4. Effect of chamosite on Bayer process

The purpose of the tests was to determine the digestion efficiency of the bauxite in different digestion conditions (temperature, retention time, concentration of Na_2O_k and amount of lime addition). The raw materials for the tests were the same as those used in predesilication tests.

Four kinds of digestion liquor were used in the tests. They are all made up of chemically pure NaOH, Na_2CO_3, $Al(OH)_3$ and de-ion water. Their chemical compositions are as below:

Table IV Composition of Digestion Liquor(g/L)

Na_2O_T	Al_2O_3	Na_2O_k	SiO_2	$(Na_2O_k)/(Al_2O_3)$
221.2	95.0	201.0	0.2	3.45
201.0	85.2	180.0	0.2	3.48
182.3	74.8	160.0	0.1	3.52
163.4	66.4	140.0	0.1	3.47

Legends: molecular formula plus ( ) represents the mole numbers of the compound

Technological investigations were carried out based on the Bayer process. Steel Bombs in melt salts were used for the test. The results are shown in Figure 5.

The presence of high silica causes high bound-soda losses in the red mud in the Bayer process, so most of the high silica digestion were carried out on the samples by Soda-lime sintering, but a part of silica content in the bauxite was in the form of chamosite, the bound-soda losses can be greatly reduced with chamosite mineral by using Bayer process.

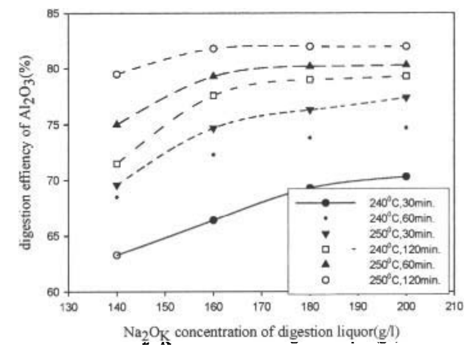

Fig 5 The influence of temperature, retention time and concentration of Na_2O_k on the digestion efficiency.

Because the bauxites are the diasporic type ore, digestion temperature of 240-250°C and lime addition were used in digestion test. Besides that, several digestion tests were conducted at 260°C(the highest digestion temperature used in autoclave for alumina production in the world) and 280-300°C (to investigate the possibility of using tube digester). The highest digestion temperature, the better digestion efficiency.

It shows that digestion temperature has the great influence on Al_2O_3 digestion efficiency. The results of Bayer digestion tests can be seen from the curves in Figure 3 that higher digestion efficiency can be achieved at 250°C and 120 minutes retention time. At the moment, the influence of Na_2O concentration (in 140-200 g/L Na_2O) on digestion efficiency is very small. If the digestion temperature is 250 °C and the retention time is only 60 minutes, in order to obtain better digestion efficiency, a digestion liquor containing 160-200 g/L Na_2O is needed.

The Silica content in sample m-1 was 10.2%. If all the silica in the bauxite was transformed into Na-Al-hydrosilicate, bound-soda losses in red mud would be more than 100kg Na_2O /T Al_2O_3. However a portion of the silica content in the bauxite was in the form of chamosite, so only part of it reacted with alkaline liquor, and the bound-soda losses in red mud was just82.3 kg Na_2O /T Al_2O_3. Because of low silica content in m-5 sample, so bound-soda losses in red mud was about 73.5 kg Na_2O /T Al_2O_3.

The silica content in the m-3 sample was less than that in m-1, however the chamosite content was also less than that in m-1, therefore, its bound-soda losses in red mud reached 110.5 kg Na_2O /T Al_2O_3.

Different content and mineralogical form of silica in these three bauxites samples had different influence on Al_2O_3 digestion character, and led to great difference in digestion efficiency of Al_2O_3.

The influence results of lime addition on Al_2O_3 digestion efficiency show that the optimum amount of lime addition varies from bauxite to bauxite. It is in about 0.03 to 0.06 CaO g/g bauxite range.

The Al_2O_3 digestion data shows that digestion rate will be increased as digestion temperature increases. At 280-300 °C, digestion reaction is finished in 5 minutes. That shows there is a possibility of using tube digester to process this kind of bauxite.

5. Settling tests of Bayer red mud

The purpose of the tests was to determine the settling rate of red mud in slurry after digestion, heights and compressed liquid/solid ratios (weight) of settled red mud. Methods of the tests: Red mud slurry produced from digestion in the Steel Bombs was added to the settling tubes, and the settling rate, heights and compressed liquid/solid ratios of settled red mud were measured.

The results are listed in Table V.

The results show that the settling properties are improved after adding flocculants. The settling rate is about 1.3-2.2 cm/min. at first 5 minutes while the height of settled red mud is about 30% after 60 minutes. The liquid/solid ratios of compressed red mud are about 4.

However, the compressibility of red mud is not so good, the height of compressed red mud reaches approximately 60% (without flocculants), while water content in red mud is about 80-85%. Therefore, it is not suitable to use settling separation for the red mud separation, while fast liquid/solid separation equipment should be used instead.

6. Conclusion

1 The results of digestion tests show that a part of silica content in this kind of bauxite exists in chamosite form, and low silica content samples are chosen for digestion by Bayer process, bound soda losses in red mud come to 73.5-82.3kg Na_2O /T Al_2O_3.

Table V. Settling properties of Bayer Red Mud

Clear liquid zone			Settling rate (cm/min)				Height of settled red mud (%)	Compressed liquid/solid of red mud (w/w)
Concentration of Al_2O_3(g/L)	(Na_2O_K) /(Al_2O_3)	Specific gravity(ml/g)	0-5 min	0-10 min	0-15 min	0-60 min		
129.5	1.54	1.22	1.49	0.87	0.62	0.20	33.3	3.78
153.6	1.55	1.25	1.25	0.86	0.62	0.20	33.7	4.12
123.6	1.54	1.20	1.95	1.08	0.75	0.21	26.6	3.11
145.9	1.55	1.24	1.26	0.84	0.61	0.20	32.1	3.57
148.3	1.55	1.23	2.17	1.17	0.81	0.23	20.6	4.08
145.1	1.56	1.23	1.88	1.07	0.74	0.21	24.8	3.76
145.5	1.56	1.24	1.45	0.88	0.63	0.20	32.5	3.43

2 Digestion properties of the bauxite in Bayer process are similar to other region diasporic bauxite, but their silica content is higher, so it should be considered to find low silica content bauxite resource (less than 6% SiO_2) or silica content in the bauxite was in chamosite form, in order to decrease bound soda losses.

3 It is not suitable to use settling separation for the red mud separation, while fast liquid/solid separation equipment and high polymer should be used instead.

7. References

1. Gu songqing, Yin Zhonglin, Zhou Huifang, et al. Behaviour of illite in the Bayer digestion preheating process of diasporic bauxite. Light Metals 1992, p109- 112.
2. Addai-Mensah J, Jones R, Zbik M, et al. Sodium aluminosilicate scale formation on steel substrates: exper imental design and assessment of fouling behavior[A].Light Metals[C]. Warrendale, Pennsylvania: TMS,2003. 25-34.
3. YIN Zhong-lin, GU Song-qing. Influence of lime adding method on scaling process in bayer preheating process of diasporic bauxite slurry[J]. The Chinese Journal of Nonferrous Metals, 2001, 11 (5): 910-914.
4. YIN Zhong-lin, GU Song qing. The influence of lime addition amount on scaling rate in preheating process of diasporic bauxite slurry [A]. Light Metals[C].Warrendale, Pennsylvania: TMS, , 2001. 139-142.
5. YAN Jin-gang, LIU Hong, WANG Jian-li. Research on mineralogical composition of scale formed in tube-digestion process[J]. Light Metals, 1999(4): 16-17.
6. YUAN Hua-jun, HUANG Fang, YUAN Yi, et al.Research on scale formed in digestion process in pingguo alumina plant-effecting factor of scale formation (2)[J]. Light Metals, 2002(9): 24-28.
7. Addai-Mensah J, Gerson A R, O'Dea A, et al. The precipitation mechanism of sodium aluminosilicate scale in bayer plants[A]. Light Metals[C]. Warrendale,Pennsylvania: TMS, 1997. 23-28.
8. Duncan A, Groemping M, Welch B, et al. The effect of silica, temperature, velocity, and particulates on heat transfer to spent bayer liquor[A]. Light Metals[C]. Warrendale, Pennsylvania: TMS, 1995. 63-70.
9. Yin Zhonglin, Gu songqing, Huang Haibo. The Influence of K2O in Spent Liquor on Bayer Process of Diasporic Bauxite [J] . Light Metals2003, 173 - 176.
10. J. M. van Baten, J. Ellenberger, R. Krishna, Scale-up strategy for bubble column slurry reactors using CFD simulations, Catalysis Today, 2003, 79(4): 59-65.
11. Qu Yin. Metallurgy Reaction Engineering [M], Metallurgy Industry press, 1988.