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Behavior of SiO_2 in the leaching process of alumina clinker with high concentration

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Abstract: It is essential for alumina production by alkaline process to know the behavior of minerals containing Al and Si in basic solution, and the behavior of SiO_2 in the process of clinker leaching is an important portion. To study the behavior of SiO_2 in the process of high concentration clinker leaching, experiments were carried out in home-made reactors. The results indicate that factors, such as temperature, time, Al_2O_3 concentration, as well as SiO_2 concentration, have profound impact on the SiO_2 and Al_2O_3 concentration of pregnant liquor during the high concentration leaching. However, sodium carbonate and free caustic soda concentrations have no remarkable effect on it, thus they are the secondary factors compared with Al_2O_3 concentration. The concentration of SiO_2 in the pregnant liquor could be reduced to a lower level when the major effect parameters of this process are controlled properly.

Key words: clinker leaching; high concentration; silica; mechanism of secondary reaction

1. Introduction

Presently in China, about 40% of alumina is produced by sintering process. Although sintering process can treat low-grade bauxite, high energy consumption and high cost is continuously restricting its further development. The main reason is that the alumina concentration of pregnant liquor is too low. Therefore improving the alumina concentration of pregnant liquor may achieve the goals of decline of material current capacity in the aqueous system, of energy consumption and of cost, and the elevation of the Al_2O_3 output [1]. So the investigations of clinker leaching with high concentration and the separation, wash of leaching slurry are critical to raise the output.

There are some arguments about the mechanism of secondary reaction that occurs when calcium orthosilicate (β-$2CaO{\cdot}SiO_2$) reacts with sodium aluminate solution which results in Al_2O_3 and soda loss in the alumina production process by sintering process. Presently, researchers in China hold two viewpoints about it: One is that the loss of Al_2O_3 and soda is caused mostly by NaOH or Na_2CO_3 and another is that it is caused mainly by $NaAl(OH)_4$ [2-6].

The conclusions mainly concern the leaching process of clinker with low concentration (Al_2O_3 concentration less then 160 g/L); however the published report about the clinker leaching with high concentration (Al_2O_3 concentration more than 160 g/L) is rarely seen. It is known that the structures of aluminum and silicon in sodium aluminate solution with high alumina and alkaline concentration greatly differ from the one with low concentration [7-8]. Therefore, the SiO_2 behavior in the leaching process of clinker with high concentration is possibly different from the situation with low concentration.

SiO_2 behavior in the leaching process of clinker with high concentration (Al_2O_3 concentration about 200 g/L) was investigated in this article. More further understanding about secondary reaction mechanism of the clinker leaching process are obtained in expectation; thus the instruction of the choice of reasonable technical conditions for high concentration clinker leaching can be theoretically provided.

2. Materials and methods

2.1. Raw materials

Clinker used in the experiment came from certain alumina factory by sintering process. Chemical com-

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position and size distribution of it after grinding are shown in Tables 1 and 2, respectively. Sodium aluminate solution was prepared with industry pure NaOH, $Al(OH)_3$ and analytical pure Na_2CO_3.

Table 1. Chemical composition of clinker wt%

Al_2O_3	SiO_2	CaO	Fe_2O_3	K_2O	Na_2O
36.30	7.83	14.20	4.41	10.60	19.25

Table 2. Granularity distribution of clinker

Granularity/mm	Content/wt%
–0.091	42.11
+0.091- –0.15	22.54
+0.15 - –0.25	10.48
+0.25 - –0.84	21.22
+0.84	3.65

2.2. Methods

Leaching experiments were carried out in home-made reactors (glycerine as heating medium, temperature control precision ±1°C). In every experiment, clinker and sodium aluminate solution was added accurately to the reactor, and leached for certain time, then the SiO_2 concentration in the filtrate was measured by silicon-molybdenum-blue spectrophotometric method, and Al_2O_3 concentration was measured by volumetric method.

3. Results and discussion

3.1. Effect of temperature on the SiO_2 concentration of pregnant liquor

Fig. 1 indicates the variation of SiO_2 concentration in the pregnant liquor with leaching temperature. As shown in Fig. 1, SiO_2 concentration prominently increases with the enhancement of leaching temperature first and largely goes down in succession. Elevation of temperature contributes to speed up the molecular transport rate, reduce the viscosity, diminish the diffusion layer thickness and aggrandize the diffusion coefficient, and all that spurs the reaction rate to also pick up. This is advantageous for the clinker leaching process beyond all doubt; and it will simultaneously promote the reaction between β-$2CaO{\cdot}SiO_2$ and sodium aluminate solution, and result in the rise of the silicon content in the solution.

It also can be found from Fig. 1 that the SiO_2 concentration remarkably decreases after temperature exceeds 100°C. This is because exorbitant temperature would cause $2CaO{\cdot}SiO_2$ to decompose intensively, thus it conduces to sharp growth of SiO_2 concentration, which made it greatly surpasses its equilibrium concentration. Consequently this promotes desilication reaction to occur; meanwhile, the formation of massive hydrogarnet and sodium aluminosilicate hydrate urges SiO_2 concentration in the pregnant liquor to decline greatly, simultaneously resulting in the massive loss of alumina and sodium oxide. The evidence of this point also can be gained from the fact that the corresponding recovery ratio of alumina is very low.

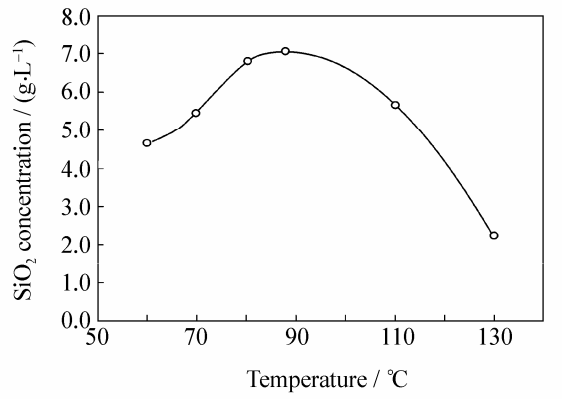

Fig. 1. Influence of temperature on the SiO_2 concentration (Time: 30 min; the ratio of liquor to solid: 4; sodium aluminate solution content: Al_2O_3 concentration 113.29 g/L, α_k (molar ratio of Na_2O to Al_2O_3) 1.84, $C_{Na_2CO_3}$ (Na_2CO_3 concentration, counts by Na_2O) 5.34 g/L; stir with low speed).

3.2. Effect of time on the SiO_2 concentration of pregnant liquor

The change of SiO_2 concentration in the pregnant liquor with leaching time is demonstrated in Fig. 2. Fig. 2 illustrates that SiO_2 concentration continuously increases with the increase of time. However, increase extent will be retarded after 20 minutes. Time within which useful ingredients of clinker were completely extracted is very short. But the stability of $2CaO{\cdot}SiO_2$ of clinker in basic solutions is relative. So the decomposition extent will be deepened versus time, and then SiO_2 concentration is to obtain the elevation to a certain degree.

Within a suitable leaching time, the beneficial reactions, such as sodium aluminate leaching, sodium ferrite hydrolization, are nearly finished, however, secondary reaction does not notably occur. $2CaO{\cdot}SiO_2$ tends to intensely decompose after this time. Therefore, any factors which lengthen the contact time between solution and red mud can increase the losses of secondary reaction.

3.3. Effect of free caustic soda concentration on the leaching process

Generally considering, only free caustic soda (K_{Na2O}) can decompose $2CaO{\cdot}SiO_2$. Free K_{Na2O} refers to the free Na_2O existed in the form of NaOH. The effect of free K_{Na2O} on SiO_2 behavior in the leaching