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Technical Note

Influence of additives on physico-chemical properties of sodium aluminate solution using seed precipitation in the Bayer process

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ABSTRACT

Various surfactants were added into the sodium aluminate solution in order to investigate the influences on the precipitation of aluminum hydroxide. The results indicate that proper additives such as C, H_2, F, etc., can not only improve the precipitation rate, but also enhance the particle size as well as the intensity of the aluminum hydroxide products. The improvement effects of the surfactants in the Bayer process are ascribed to the modification of the physical-chemistry properties of the sodium aluminate solutions. Surface tension, viscosity and conductivity of sodium aluminate solution were studied in detail, and it seems that moderate decrease of surface tension as well as the decrease of the viscosity is in favor of the production of aluminum hydroxide with high yield, large particle size and high intensity.

Keywords: Surfactants; Sodium aluminate; Bayer process

1. INTRODUCTION

One of the major processes in the production of $Al(OH)_3$ is to add the crystal seed, Al_2O_3 , into the sodium aluminate solution to precipitate another $Al(OH)_3$ with constant stirring under the temperature-decreasing condition. In recent years, investigations concerning Bayer process mainly focused on the factors affecting precipitation of $Al(OH)_3$ from Bayer solution as well as the mechanisms of the process (Pradhan *et al.*, 2001; Bhattacharya *et al.*, 2002; Paulaime *et al.*, 2003). However, at present, there is still some products of $Al(OH)_3$ in our country can not meet the requirements of producing sandy Al_2O_3, because of the low precipitation rate (Chen, 1986). For that matter, much work has been done by researchers. Recent reports show that the precipitation process and the quality of the $Al(OH)_3$ can be greatly enhanced by adding certain amount of surfactants into the sodium aluminate solution (Harrey, 1990; David, 1991; Lester, 1991; Arnwald, 1995; Moody, 1995; Xue *et al.*, 1998). When the surface active substances were added into the sodium aluminate solution, the physical-chemistry properties would be changed and this will inevitably influence the quality of $Al(OH)_3$ and its precipitation process.

2. EXPERIMENTAL

2.1. Major apparatus

The major apparatus used are given below: A blade-paddle mixer tank, a Model RPW-09 melting point comprehensive analyzer, a Model 1054BT electric conductivity apparatus, a Model LB-801 super constant temperature bath, and capillary viscometer.

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2.2. Methods for measuring

- The precipitation ratio η is defined as: $\eta=[1-a_\alpha/a_m]\times 100\%$

  Where a_α denotes the molecular ratio of the primary solution and a_m stands for the molecular ratio of the original solution. The measurement of Na_2O_T, AL_2O_3 and Na_2O_k was performed with the chemical method.
- The method for the measurement of the particle size.

  The particle size of the $Al(OH)_3$ products was analyzed with a sifter and/or a image analyzer (Wang *et al.*, 2002). The particle size of the products was expressed with the mass fraction of the particles that was lower than 45um in diameter.
- The method for measurement of intensity

  The intensity was performed with a simulated ALCDA attrition index apparatus, with the pressure (N_2) 0.40 Mpa and the flow rate of 2.8m^3/h lasting 15min. The intensity of $Al(OH)_3$ products was expressed with the attrition index. The definition is as follows:

$AL=[(A-B)/A]\times 100\%$

Where A is the mass fraction of the particles that was larger than 45um in diameter before blowing and B denotes mass fraction of the particles that was larger than 45μm in diameter after the blowing.

2.3. The experimental materials

- The sodium aluminate solution was confected according to the molecular ratio and the concentration expected with the circulating mother liquor provided by the aluminium factory of Shanxi province.
- The surfactants A, G, and C were purchased abroad and the other was produced in our laboratory.

2.4. The experimental conditions

The concentration of alumina is ranging from 160 to 180g/l with the molecular ratio at 1.5, containing 570g/l of the solid seed. The precipitating time is 60h. The temperature was evenly decreased from 75 to 54°C in the whole process.

3. RESULTS AND DISCUSSION

3.1. The enhanced precipitation process of sodium aluminate solution in the presence of additives

In the Bayer process of precipitation, high-intensity, large-size of $Al(OH)_3$ products can be obtained by adding proper amount of additives. In this study, three kinds of abroad products: A, G and C were employed and some kinds of surfactants were used which were produced according to the general processes. The results were shown in Table 1 and 2.

Table 1
The effects of additives on precipitation ratio, particle size as well as intensity of aluminum hydroxide (addition amount: 100mg/l)

Additive	Precipitation ratio (%)	Number of -45μm particle (%)	Attrition index (%)
blank	20.84	24.92	17.21
A	19.24	23.98	13.36
G	21.25	25.84	13.16
C	21.20	24.03	12.15
I	18.74	21.00	16.74
blank	21.06	25.81	17.98
F	21.68	28.02	10.04
H_2	22.48	24.94	14.30
H_5	17.84	26.92	14.00
H_6	16.80	24.32	17.88

Table 2
The effects of additives on precipitation ratio, particle size as well as intensity of aluminum hydroxide (addition amount: 200mg/l)

Additive	Precipitation ratio (%)	Number of -45μm particle (%)	Attrition index (%)
blank	20.96	25.81	17.85
A	21.56	24.11	12.64
G	21.04	24.30	12.68
C	21.88	24.62	12.86
I	19.32	28.24	16.90
blank	20.88	25.56	17.23
F	23.84	24.20	11.80
H_2	23.53	26.60	17.98
H_5	18.01	26.96	13.77
H_6	18.08	24.94	18.87

It can be found from the above two tables that the influences of addition of the additives are differently according to the kinds they belong to and the amount of the addition. The flowing additives: C, F and H_2, can not only improve the precipitation rate, but also can enhance the particle size and the intensity of the products. Author had discussed the microcosmic mechanism of additives in relative paper (Zhao *et al.*, 2003).

The precipitation process was mainly depended on the diffusion and the surface reaction (Xie, 2000). When the surfactants were added in this process, the physical and chemical properties of the solution such as the viscosity, surface tension etc. would be apparently changed. Consequently, some surfactants can be employed, in order to fasten the diffusion rate and enhance formation of the precipitation.

3.2. The influence of the additives on the surface tension of the solution

In order to explore the influence of the additives on the surface tension, various kinds of additives were employed, keeping the concentration of Al_2O_3 in the solution from 160 to 180g/l with a molecular ratio of 1.52. A melt comprehensive analyzer was used to measure the surface tension at 75°C. The variations of the surface tension of sodium aluminate solution with the concentrations of the additives were shown in Figure1.

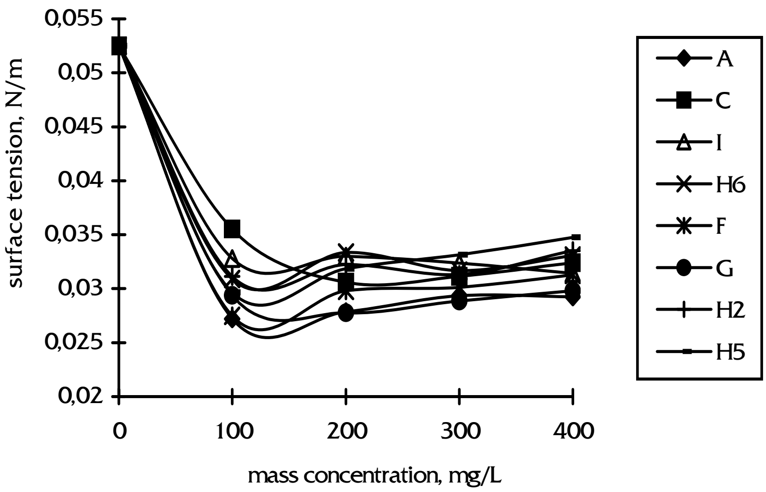

Figure 1. Effect of amount of additives on the surface tension

From Figure 1, it can be seen that all of additives used are enable to make the surface tension of the solution decease greatly, appear a lowest value and then go to a stable state. Of course, different additives have their own break point of concentration and the decreasing amplitudes are also different. Moreover, it is not easy to say exactly the relation between the decrease of the surface tension and the enhancement of the precipitation. Although the lower of the surface tension is favorable to the formation of crystal nucleus, over decreasing can lead to the high forming rate of crystalline particles, making too much branching crystals on its surface, resulting the intensity decrease. The experiments showed that when the surface tension of the sodium aluminate solution was controlled in the range from 0.015 to 0.02N/m, the Al $(OH)_3$ products precipitated bear good both intensity and particle size.

3.3. Effect of additives on the viscosity of the sodium aluminate solution

A capipillary viscometer was used to measure the viscosity of the solution in order to investigate the influence of the additives on the viscosity of the solutions. The operating conditions are given below: the concentration of $Al(OH)_3$ is 160-170g/l; molecular ratio 1.52 and temperature at 75°C. The whole process was performed with stirring well.

Figure 2 shows that the viscosity of the sodium aluminate solution can be remarkably changed when the surfactants were added. Generally, the additives play an important part in the intensity and particle size of $Al(OH)_3$ because of decreasing the viscosity of sodium aluminate decrease. At the beginning of precipitation, the viscosity was always below the blank value, making the diffusion speed, which is in agreement with the precipitation mechanism of the sodium aluminate solution.

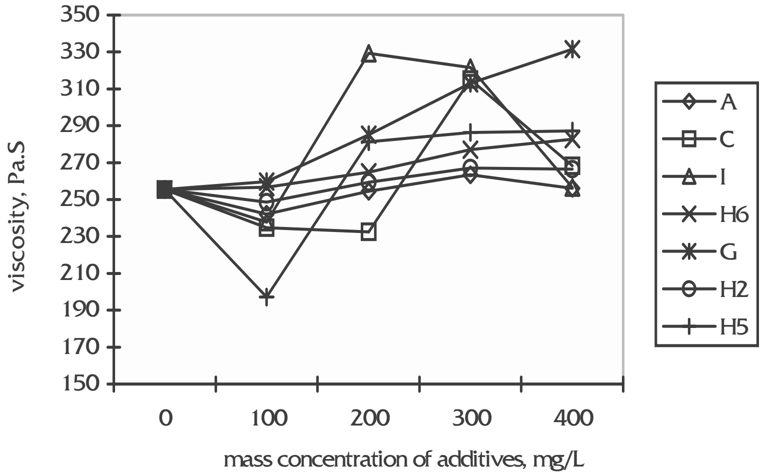

Figure 2. Effect of the amount of additives on the viscosity

2.4. Effect of additives on the conductivity of solution

In this part, a 1056BT model conductivity apparatus was used to measure the solution conductivity for studying the effect of the additives on the conductivity of solutions. The original solution was made by 160-170g/l of aluminium oxide (molecular ratio 1.52) with various additives at 75C. The results were shown in Figure 3.

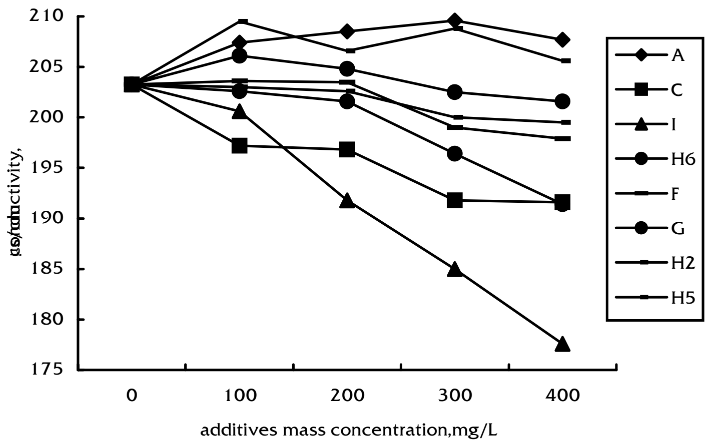

Figure 3. Effect of amount of additives on the conductivity

The experiments indicated that the five additives: F, H_2, H_5, H_6, and A have little effect on the conductivity, while G or C can make a little, and only additive I can make it decrease significantly. This can be understood by the facts that the additive I is a kind of anion surfactant, and when the amount of the addition is over the CMC (critical micelle concentration), the conductivity became unchanged. While the degree of ionization of surfactants decreases with the increases of its concentration, as a result, the conduction of the solution decreases with the increasing of the surfactant concentration (Shen *et al.*, 1997). For the nonionic surface-active agents such as model F, the addition concentration has little effect on the solutions conductivity (Zhao, 1996). There seems no relationship between the concentration and the solution conductivity for the other additives due to the complexity of the system.

4. CONCLUSIONS

Proper surfactants such as C, H_2, F, etc., added into sodium aluminate solution can not only improve the precipitation rate, but also enhance the particle size as well as the intensity of the aluminum hydroxide product.

The improvement of the precipitation process of aluminum hydroxide can be ascribed to the variations of the physical-chemistry properties of the sodium aluminate solutions after addition of the surfactants. Moderate decrease of surface tension of the solution is in favor of the production of aluminum hydroxide with a better quality. The additives which can lead to the decrease of the viscosity of the solution can enhance the intensity and particle size of the product. Although there seems no obvious relationship between the conductivity of the solution and the quality of the product, it can be implied that the best additives exert their influences by adjusting the crystal growing rate as well as ion diffusion rate in the solution to optimal values.

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