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Effect of 20 kHz ultrasound on alumina hydrate precipitation from seeded sodium aluminate solution①

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[Abstract] The effect of 20 kHz ultrasound on alumina hydrate precipitation from seeded sodium aluminate solution was studied. Compared with alumina hydrate precipitation without treatment of ultrasound, the precipitation time is reduced from 30 h to 15 h when the precipitation ratio is 45% under 20 kHz ultrasound. Furthermore, agglomeration is increased and the growth rate of alumina hydrate is increased under 20 kHz ultrasound by comparing the crystal size distribution and the SEM photographs. As a result, the average size of alumina hydrate is increased by 3.7 μm. The structure of product is not changed according to the results of X-ray powder deflection.

[Key words] ultrasound; alumina hydrate; induction time; agglomeration; crystal growth
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1 INTRODUCTION

In the alumina industry, precipitation of alumina hydrate in the Bayer process is a very important operation. In numerous instances when rigid product specification is given the process become a bottleneck of the plant. Scientists have worked on increasing productivity[1, 2] or improving quality[3, 4]. But the various phenomena occurring during the precipitation make optimizing the balance between quality and productivity highly complex.

Ultrasound causes high-energy chemistry through the process of acoustic cavitation: the formation, growth and implosive burst of bubbles in a liquid. During cavitational burst, heating the bubbles occurs intensively. These localized hot spots have temperature about 5 000 ℃, pressures about 500 atmosphere, and a few microseconds lifetime. Improvements in chemical reaction under ultrasound have been widely studied[5~8]. The precipitation rate of alumina hydrate is improved evidently under 20 kHz ultrasound. The mechanism of enhancement on precipitation of alumina hydrate is the solution absorbs the cavitation energy generated by ultrasound and activation energy of precipitation is decreased[9, 10]. This study explores the effects of 20 kHz ultrasound on precipitation ratio, agglomeration and crystal growth.

2 EXPERIMENTAL

The equipment includes constant temperature water bath, stainless steel crystallizer, impeller and ultrasonic generator as described in Fig. 1. The ultrasonic power was adjustable within 350 W.

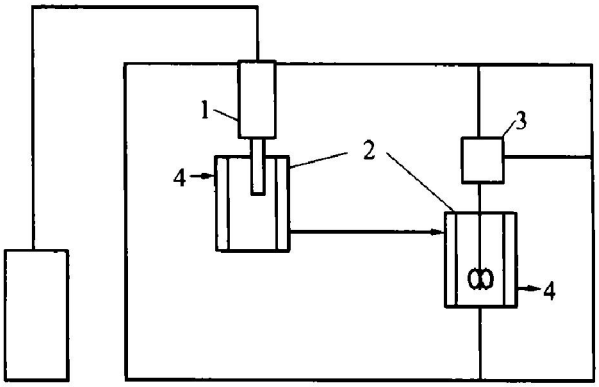

Fig. 1 Schematic diagram of experiment
1—Ultrasonic generator; 2—Stainless steel crystallizer; 3—Impeller; 4—Constant temperature water

The composition of sodium aluminate solution used for the experiment was: $c(Na_2O) = 150$ g/l, $\alpha = 1.45$. Where, $c(Na_2O)$ is the concentration of caustic sodium expressed in Na_2O, α is the molecular ratio of Na_2O to Al_2O_3. The experiment conditions were: the experiment temperature of 50 ℃, the ratio of Al_2O_3 amount in seed to Al_2O_3 amount in sodium aluminate of 1.0.

3 RESULTS AND DISCUSSION

3.1 Effect of ultrasound on precipitation ratio

Fig. 2 shows the effects of 20 kHz ultrasound on the alumina hydrate precipitation ratio. The precipitation

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time is reduced from 30 h to 15 h under 20 kHz ultrasound of 96 W when the precipitation ratio is 45%. However, the enhancement is decreased when the output power is 286 W. The cavitation is affected because the bubbles maybe get too large to burst when the output power is too high. Researches below are worked on the output power of 96 W.

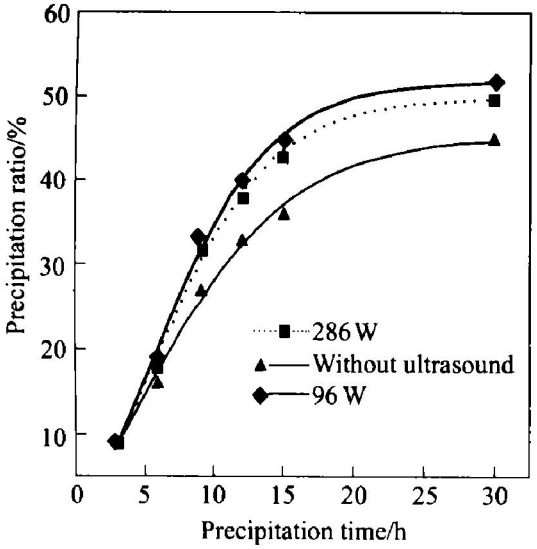

Fig. 2 Effect of 20 kHz ultrasound on precipitation ratio

3.2 Effect on agglomeration under 20 kHz ultrasound

Table 1 is the crystal size distribution of seed. Tables 2 and 3 present the effect of 20 kHz ultrasound on the agglomeration. It can be seen that the agglomeration are enhanced under ultrasound. The percentage of 60~80 μm is decreased by 3.5% and the percentage of larger size is increased under 20 kHz.

3.3 Effect of 20 kHz ultrasound on crystal growth

Tables 4, 5 show the effects of 20 kHz ultrasound on crystal growth. It is found that crystal growth rate is increased under 20 kHz ultrasound. Compared with the product without ultrasound, the mass average size is increased by 3.7 μm and surface area is decreased by 244.7 cm^2/g under 20 kHz ultrasound.

Fig. 3 shows the SEM photographs of alumina hydrate with and without ultrasound when the precipitation time is 12 h. It also can be seen that the product under 20 kHz ultrasound is more uniform than the product without ultrasound.

Table 1 Crystal size distribution of seed

Crystal size/μm	< 22	22~ 44	44~ 66	66~ 88	88~ 110	> 110
ω/%	0.49	8.10	32.10	7.70	9.47	22.14

Table 2 Crystal size distribution of product after 6 h precipitation

Crystal size/μm	ω/%*	ω/%**
< 20	6.70	10.30
2~ 40	8.97	9.28
40~ 60	16.30	14.80
60~ 80	24.20	20.70
80~ 100	18.50	19.40
100~ 140	11.95	13.40
> 140	13.38	12.12

* —Precipitation without ultrasound;

* * —20 kHz ultrasound (The same in Table 4).

Table 3 Characteristics of product after 6 h precipitation

Precipitation condition	Mass average size/μm	Surface area/ ($cm^2 \cdot g^{-1}$)
Without ultrasound	74.8	633.44
20 kHz ultrasound	74.9	763.52
Seed	73.3	367.04

Table 4 Crystal size distribution of product after 12 h precipitation

Crystal size/μm	ω/%*	ω/%**
< 20	18.49	19.90
2~ 40	9.70	9.13
40~ 60	1 885	14.20
60~ 80	25.97	23.60
80~ 100	11.60	5.67
100~ 140	12.63	11.12
> 140	2.76	16.38

Table 5 Characteristics of product after 12 h precipitation

Precipitation condition	Mass average size/μm	Surface area/ ($cm^2 \cdot g^{-1}$)
Without ultrasound	61.9	1 275.4
20 kHz ultrasound	65.6	1 030.7

3.4 Comparison of X-ray powder diffraction

X-ray powder diffractions of product with and without ultrasound shows that the structure of product isn't changed in the precipitation with 20 kHz ultrasound.

4 CONCLUSIONS

1) The precipitation time is reduced from 30 h to 15 h when the precipitation ratio is 45% under 20 kHz ultrasound.

2) It would be increased agglomeration and enhanced the growth of alumina hydrate under 20 kHz ultrasound.

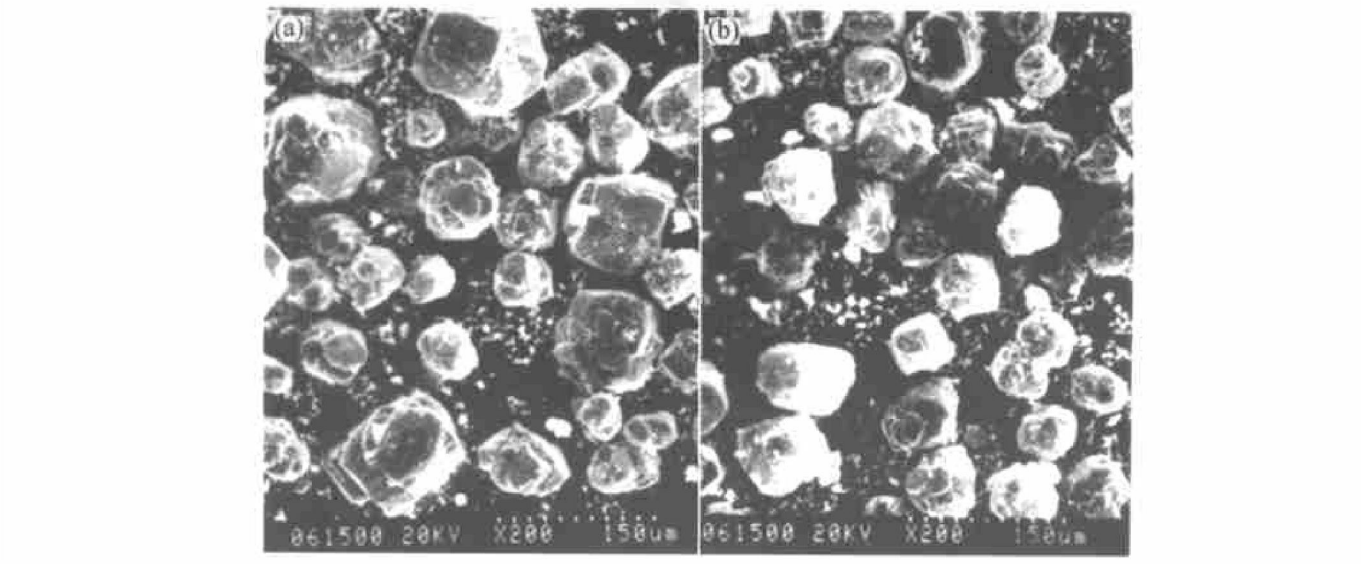

Fig. 3 Representative photomicrographies of alumina hydrate with and without ultrasound (precipitation time is 12 h)
(a) —Without ultrasound; (b) —20 kHz ultrasound

3) The structure of alumina hydrate is not changed under 20 kHz ultrasound.

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