Light Metals 2012 *Edited by: Carlos E. Suarez*
TMS (The Minerals, Metals & Materials Society), 2012

Physical Simulation on Mixing Uniformity in Seed Precipitation Tank

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Keywords: seed precipitation tank, cold water model, mixing uniformity

Abstract

The suspension and dispersion of $Al(OH)_3$ particles in seed precipitation tank, which may affect the quality and output of alumina besides the deposit on the bottom of the tank, is one of the key steps in Bayer process. In order to solve these problems, the solids concentration profiles of $Al(OH)_3$ particles were investigated by cold water experiments under simulated industrial conditions. The results showed that, the mixing uniformity in the whole tank improved with the increase of impeller off-bottom clearance when used the impeller of small diameter ($D / T \leqslant 0.6$), and it deteriorated when enlarged the impeller ($D / T = 0.65 \sim 0.7$). The mixing effects can be improved by increasing the impeller diameter and stirring speed, meanwhile the influence of impeller off-bottom clearance was weakened. But the impeller diameter and stirring speed should be controlled in appropriate ranges for the consideration of power consumption and mixing efficiency.

Introduction

The seed precipitation step was one of the key steps in the Bayer process for the production of alumina, and it has great influence on alumina product's outputs and quality and also has indirect effect on other procedures[1]. For it has many advantages[2], now the mechanically agitated precipitation tank has became the major equipment of seed precipitation step in China.

The mixing effect in a vessel agitated was largely determined by types and structures of the impeller[3]. At the beginning, the original Intermig impeller was used in Shanxi Aluminum Plant in 1997. Compared with the common blade-inclined agitators, the original Intermig impeller had improved the suspension of $Al(OH)_3$ particles, and power consumption declined largely. However, to prevent sedimenting of solid particles should be special noticed[4]. The Intermig impeller was introduced by Shenyang Aluminum & Magnesium Engineering & Research Institute (SAMI), and it was improved on the bottom impeller, called improved Intermig impeller, which enhance the effect of mixing. Especially, the deposition of solid particles was reduced in the tank bottom. So it is necessary to analyze this step systematically.

In this work mixing uniformity (C/C_{avg}) were performed in a seed precipitation tank agitated with improved Intermig impeller by using the cold water experiment method.

By this research we intended to investigate the factors influencing the mixing uniformity and power consumption , and it has important theoretical and practical significance for alumina industry.

Experimental Principle and Equipment

Water Model Principle

Geometrical Similarity Geometry similarity requires the dimension is in proportion between the large and small reactors. Therefore, when determining the size of the large agitator, the small agitator's dimensions including the tank diameter and height, impeller diameter and width, baffles and other dimensions can be also determined according to the geometrical similarity condition. The water model was made in accordance with the scaled down size 1:33 of the prototype of industrial seed precipitation tank. Table 1 shows the dimensions of the water model.

Dynamical Similarity Under the geometrically similar condition, the relation of the rotational speeds between the large and small agitator can be usually expressed as:

$$N_L = N_S (D_S / D_L)^X \quad [1]$$

N: Rotational speed, r/s; *D*: Diameter of the impeller, m;

X: Amplification index which was usually from 2/3 to1; Subscript S: Small agitator; Subscript L: Large agitator.

For the solid-liquid suspension system, amplification factor was ND or N^4D^3. So, the value of X was from 3/4 to 1.

Table 1 Ranges of parameters in experiment

T			425mm		
D/T	0.6		0.65		0.7
C/T	0.024	0.047	0.071	0.094	0.118
n			100~150 rpm		

D: Diameter of the impeller; T: Diameter of the tank

C: impeller off-bottom clearance; n: Rotational speed.

Experimental Equipment

Agitator and Concentration Analyzer Figure 1 showed the equipment of water model experiment, the tank and baffles were made by plexiglass. The impeller height and rotational speed could be freely adjusted and the value of stirring power could automatically be outputted.

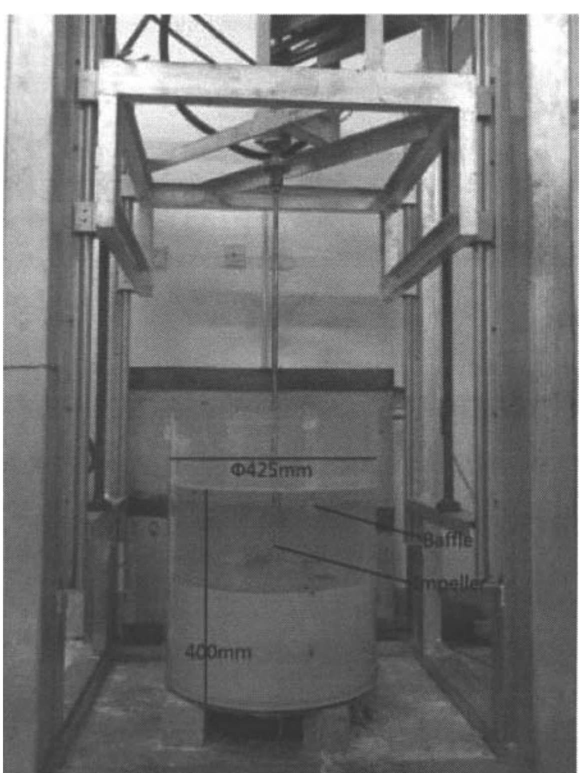


Fig.1 Equipment of water model experiment

The profile of local solid concentrations on the water-glass bead particles in liquid-solid system were measured by using a PC6D fiber optic reflection probe and analyzed in different conditions. Figure 2 showed the measuring points in the tank.

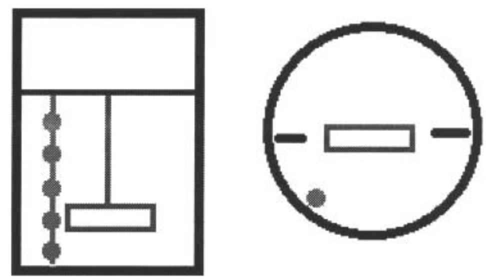
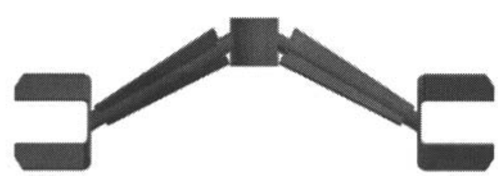
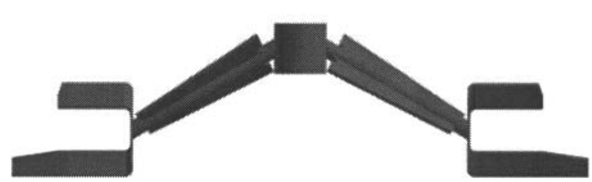


Fig.2 Measuring points of concentration

Intermig Impeller The Intermig impeller has been widely used in solid-liquid suspensions, liquid-liquid dispersion and gas-liquid dispersion and heat transfer[3], and it was introduced and improved for seed precipitation tank by SAMI[5]. Figure 3 showed the different structures between original and improved Intermig impellers. Both the two impellers had two parts, main blade and accessorial blade. Compared to ordinary impeller, the improved Intermig impeller was lengthened which greatly increased the mixing strength, and significantly improved blending effect.



(a) Original Intermig impeller



(b) Improved Intermig impeller

Fig.3 Original and improved Intermig impeller

Material Selection Theoretically speaking, using sodium aluminate solution and aluminum hydroxide particles could be more close to the industrial environment. However, because of the strong corrosive of sodium aluminate solution, it was difficult to be used in water model experiment. So we used materials of which physical properties were similar to sodium aluminate solution and aluminum hydroxide solid, that not only ensure the experimental requirements but also increase the safety of the experiment.

In this work calcium chloride solution and glass beads were used instead of sodium aluminate solution and aluminum hydroxide solid. Table 2 showed the physical parameter of these materials. It was worthy of note that the density and viscosity of calcium chloride solution with a mass concentration of 35% were very similar to sodium aluminate solution.

Table 2 Comparisons of physical parameters

Physical Parameters	Density /kg/m^3	Viscosity /cp
Sodium Aluminate Solution	1330	3.5
Running Water	1000	1.52
Calcium Chloride Solution (35%)	1325	9
Aluminum Hydroxide	2430	Granularity: about 100μm
Glass Beads	2380	

Results and Discussion

Uniformity on the bottom

Experimental condition: D/T=0.6, n=130rpm~150rpm, C=10mm~50mm.

The uniformities on the tank bottom with different C and n were showed in Figure 4. Under the condition of D / T = 0.6, the concentration on the bottom showed the tendency to descend with the increasing of C at a low rotational speed. Increasing the rotational speed may lower the concentrations of solid particles on the bottom. Meanwhile, the influence of impeller off-bottom clearance was weakened. The values of uniformities were close to 1 at 150rpm which meant it was closer to theoretical concentration under this condition, what is more evenly mixed.

Experimental condition: D/T=0.65, n=130rpm~150rpm, C=10mm~50mm.

When enlarging D/T to 0.65, the changing of tendency was showed in Figure 5. The concentrations on the bottom increased as C increased at the rotational speed from 130rpm to 140rpm. Similarly, high rotational speed may lower the concentrations on the bottom and weakened the influence of impeller off-bottom clearance to the uniformity. When C is not too large, it could get good results at lower rotational speeds. For instance, we could see clearly from Figure 5 that the value of C_d/C_{avg} was close to 1 under the conditions of C/T=0.024 and n=135rpm. So impeller off-bottom clearance should not be so large.

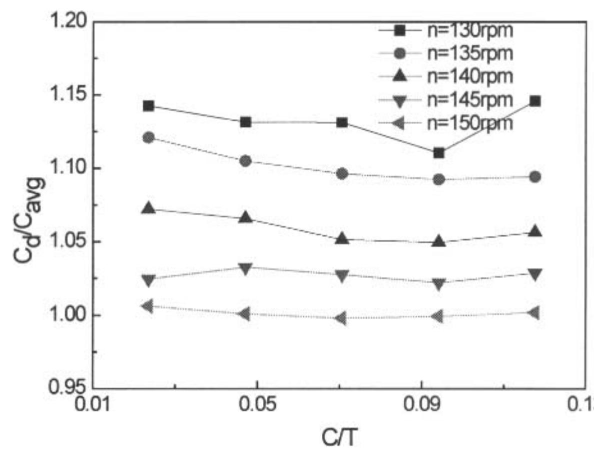


Fig.4 D/T=0.6, bottom concentration with different C/T and n

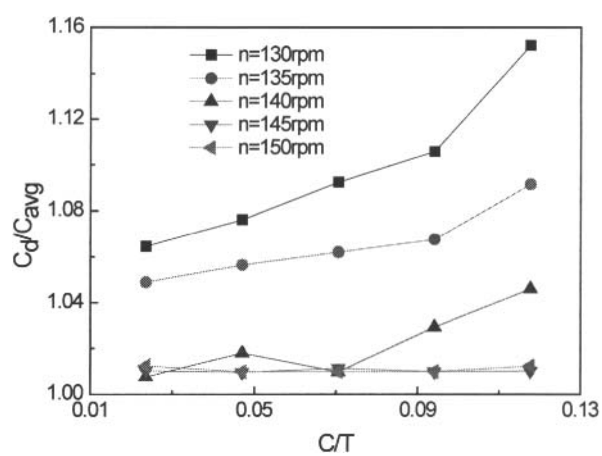


Fig.5 D/T=0.65, bottom concentration with different C/T and n

Experimental condition: D/T=0.7, n=130rpm~150rpm, C=10mm~50mm.

When enlarging D/T to 0.7, the mixing uniformity represented a great improvement that was showed in Figure 6. The solid particle concentrations were almost all close to the theoretical concentration of which value was 0.33. Only at the condition of n=130rpm, the value of C_d/C_{avg} was a little bigger.

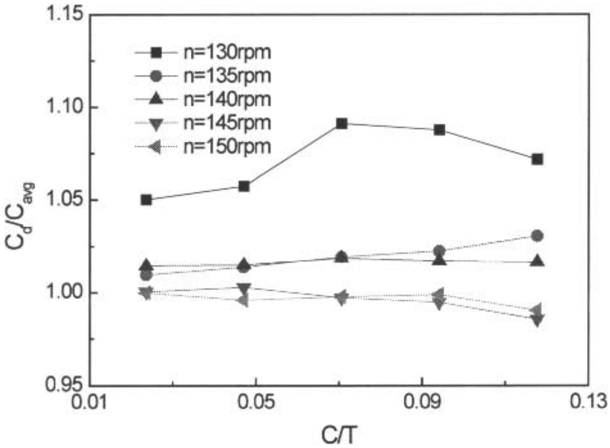


Fig.6 D/T=0.7, bottom concentration with different C/T and n

Axial Uniformity

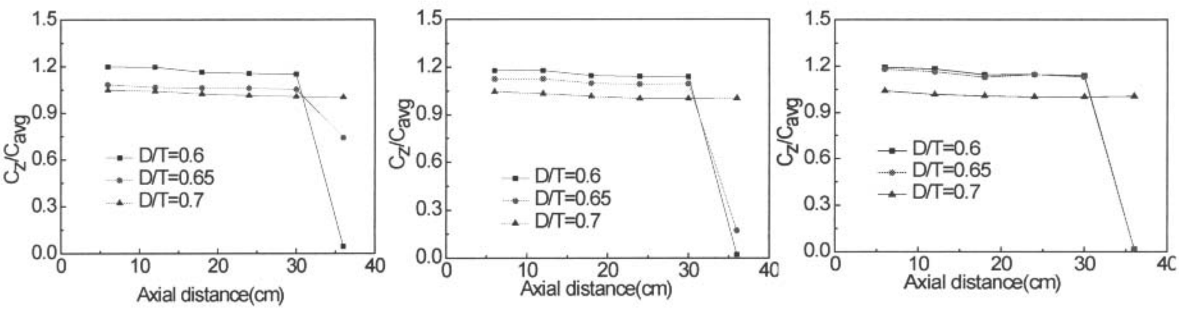
Experimental condition: D/T=0.6、0.65、0.7, n=130rpm, C=10mm、30mm、50mm.

Figure 7 showed the axial uniformity with different conditions. Increasing the impeller diameter could significantly improve the mixing effect of solid particles at a certain rotational speed, and the volume of supernatant also reduced. C had significant effect on axial concentration, especially near the surface at the of n=130rpm, D/T=0.65. As C increased, the two concentration curves of D/T=0.6、0.65 got closer gradually. Specifically, The two curves almost coincide at the condition of C=50mm.

Power Consumption

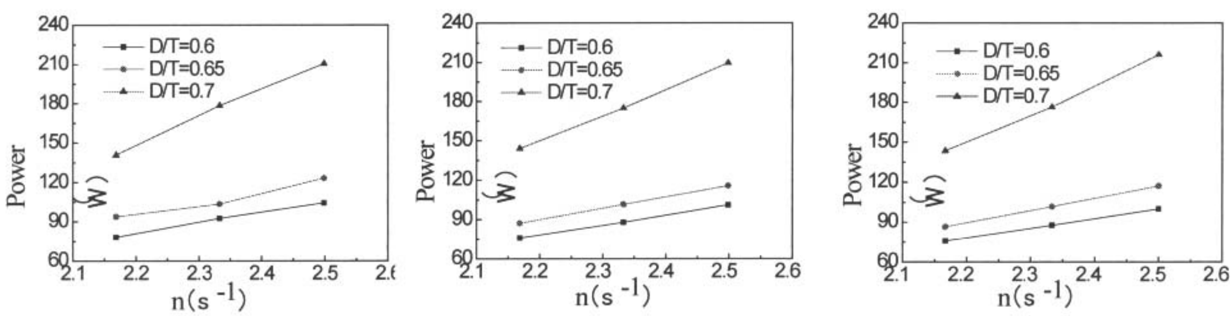
Experimental condition: D/T=0.6、0.65、0.7, n=130rpm, C=10mm、30mm、50mm.

Figure 8 showed the Power Consumption with different conditions. The impeller diameter and rotational speed has a big influence on the stirring power, and longer D or higher n needs much more power consumption, and C had little effect on the stirring power, which can be ignored.



C=10mm C=30mm C=50mm

Fig.7 Axial uniformity with different D/T and n



C=10mm C=30mm C=50mm

Fig.8 Power consumption with different D/T and n

Conclusion

We could find out the factors affecting mixing uniformity and power consumption by the comparison of results under different conditions. results, we can get the conclusions below:

(1) The improved Intermig impeller may improve suspension and reduced the deposition of aluminum hydroxide particles on the tank bottom.

(2) The mixing uniformity in the whole tank improved with the increase of impeller off-bottom clearance when used the impeller of small diameter (D/T≤0.6), and it deteriorated when enlarged the impeller (D/T=0.65~0.7). The mixing effects can be improved by increasing the impeller diameter and stirring speed, meanwhile the influence of impeller off-bottom clearance was weakened.

(3) The rotational speed and D had big influence on the stirring power, higher speed and longer diameter of impeller needed more power. By comparison, the C had little effect on the stirring power.

In conclusion, in order to get the good mixing effect, C should not be too small with the impeller of small diameter and not be too large with the impeller of big diameter. The mixing effects can be improved by increasing the impeller diameter and stirring speed, meanwhile the influence of impeller off-bottom clearance was weakened. But for the consideration of power consumption, the impeller diameter and rotational speed should be controlled in appropriate ranges.

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Acknowledge

The authors acknowledge the support of the National Natural Science Foundation of China (NO.50974035, 51074047).