AA08 - Performance of Wide-Channel Welded Plate Heat Exchanger for Bayer Precipitation Process

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Abstract

Based on the agglomeration, the hydromechanical and the thermodynamic mechanisms, the scaling characteristics of sodium aluminate solution on the heat transfer wall were explored. The performances of the wide-channel plate heat exchanger after scaling were investigated. With scaling on the surface, the heat transfer coefficient and the slurry flow rate would decrease, and the pump's power consumption and the pressure drop of the heat exchanger increase. The precipitation yield would also be impacted due to heat transfer deterioration. In addition, scaling on the heat transfer surface would also cause higher local flow rate and erosion acceleration, thereby shortening the equipment service life. Finally, the vertical wide-channel plate heat exchanger and the equipment quantitative management implemented by an intelligent IIot platform are proposed to improve the equipment performance.

Keywords: Sodium aluminate, scaling, wide-channel plate heat exchanger, maintenance.

1. Introduction

In the alumina production, the stability of sodium aluminate solution greatly restricts its precipitation yield. Because of the controllability, cooling system has become the most effective means to regulate the precipitation process and improve the precipitation yield while maintaining the alumina quality at the desired levels. However, due to a number of operating and technical reasons of Bayer process, precipitation of aluminium hydroxide and some other chemical components takes place at the heat transfer wall surface, which reduces the performance of the equipment over a period of time and if remedial steps are not taken, the likelihood of the equipment failure could not be ruled out.

In the following, CFD simulation was conducted and a workstation with two XEON processors with 3.40 GHz and 128.0 GB RAM was used. This paper will introduce the microscopic mechanism of aluminum hydroxide scaling on the heat transfer wall, study the characteristics of wide-channel welded plate heat exchanger after scaling in the flow passage, and finally propose a novel approach i.e. "vertical wide-channel plate heat exchanger" for cooling of slurry in the precipitation area and the equipment quantitative performance management implemented by an intelligent IIot platform.

2. Microscopic Mechanism of Scaling

In the heat exchanger, scaling often takes place on the heat exchange surface, as shown in Figure 1. This is mainly because fine aluminium hydroxide particles precipitate out from the low-temperature sodium aluminate solution in the boundary thermal sublayer, which directly stick to the wall, or bond with other fine aluminium hydroxide particles and then stick to the surface. The particle agglomeration mechanism, the particle capture mechanism in the viscous sublayer, and the thermodynamic mechanism of scaling will be introduced in the following.

Figure 1. Scale on the heat transfer wall.

2.1 Agglomeration Mechanism

In sodium aluminate solution, small aluminum hydroxide particles are first combined by collision to form a flocculate, which is further bonded to form a firmer agglomerate. STEENTON found that the agglomeration mainly occurred between fine particles with similar sizes, and it was difficult to occur between particles with different particle sizes [1]. Since the agglomeration could be explained by the binary collision theory, LI calculated the collision frequency of two particles, and the results showed that it was difficult to coalesce between coarse particles [2]. Although the collision frequency between fine particles and coarse particles was high, there was no coalescence between them due to the low activity of coarse seeds. Therefore, the particles smaller than certain critical size could form agglomerates, and the agglomeration efficiency increases with the decrease of particle diameter.

2.2 Hydrodynamics Mechanism

In the viscous sublayer, particle movement has an important effect on the scaling: (1) - If the particle size is small enough within the viscous sublayer, particle is completely trapped and travels at very low velocity (see Figure 2). (2) - When the particle size is large compared to the thickness of the viscous sublayer, the impingements between the particles and the wall become significant. So, the interaction mechanism between the particles and the wall scaling strictly depends upon the ratio of particle size to boundary layer thickness. In order to quantitatively describe the mechanism, a dimensionless particle size d_p^+ is proposed [3, 4]:

$$d_p^+ = \frac{\rho_f d_p u_f^*}{\mu_f} \tag{1}$$

$$u_f^* = \sqrt{\tau_{w,f} / \rho_f} \tag{2}$$

where u_f^* is the friction velocity of the fluid, namely the square root of the ratio between the fluid wall shear stress $\tau_{w,f}$ and the fluid density ρ_f.

Figure 11. IoT monitoring graphical interface.

5. Conclusions

The mechanism of agglomeration, hydromechanics and thermodynamics of scaling of aluminum hydroxide on the heat transfer wall were introduced. After scaling, the heat transfer coefficient and the slurry flow rate decrease, the pump's power consumption and the pressure drop on the slurry side increase. The precipitation rate of the sodium aluminate solution decreases with the decrease of heat transfer coefficient. Scale could also accelerate plate erosion and shorten the service life of the equipment. Finally, a verticle wide-channel welded heat exchanger and an intelligent maintenance system for heat exchanger used for cooling of the sodium aluminate solution are proposed. In the intelligent system, the difference between the monitor parameters and the predicted values calculated on the assumption that the heat transfer wall is clean could reflect the performance state of the heat exchanger.

6. References

1. M. L. Steemson, E. T. White, R. J. Marshall, *Mathematical model for the precipitation section of a Bayer plant*, Proceedings of the Technical Sessions at the 113th TMS Annual Meeting, California, *Light Metals 1984*, 237.
2. W. Li, J. Yin, Study on the agglomeration kinetics of gibbsite particle. *Science & Technology Review*, 2007, 25 (22), 27-31.
3. G. V. Messa, M. Malin, S. Malavasi, Numerical prediction of fully suspended slurry flow in horizontal pipes. *Powder Technology*, 2014, 256 (256), 61-70.
4. G. V. Messa， Malavasi, Stefano, Improvements in the numerical prediction of fully suspended slurry flow in horizontal pipes, *Powder Technology*, 2015, 270, 358-367.
5. R. Hu, L. Ren, D. Wang, et al., Numerical simulation of fully developed liquid-solid flow in vertical narrow channel, *Journal of Chemical Industry and Engineering*, 2018, 69 (8), 3408-3417.
6. L. Ren, X. Zhao, S. Zhang, Hydrodynamic investigation of liquid-solid flows in horizontal narrow rectangular channel, *Chemical Industry and Engineering Progress*, 2018, 37, (6), 2092-2100.
7. L. Ren, X. Zhao, S. Zhang, Hydrodynamic investigation of slurry flows in horizontal narrow rectangular channel, International Journal of Heat and Technology, 2017, 35, (4), 730-736.