Simulation of Solids Flocculation by CFD-PBM Method

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Abstract

In alumina production of great importance is separation of suspension into liquid and solid components. Settling rate depends significantly on the size of solid particles; therefore, one of the ways to raise efficiency of a thickener is to enlarge the effective size of solid particles by means of reagents – flocculants. Flocculation process is accompanied by simultaneous growth and breakage of agglomerates under the influence of turbulent forces. Hydrodynamic conditions under which it proceeds have significant effect on dynamics of the process. In the paper, a CFD PBM method is considered comprising solution of population equation balance, describing a process of agglomeration and breakage of flocs in the environment of computational fluid dynamics. In the paper laws of agglomeration and breakage of flocs are provided, a laboratory installation and technique enabling to determine parameters of laws of flocs agglomeration and breakage is described, examples of thickeners simulation by CFD-PBM method are given. The proposed CFD-PBM method allows to predict growth dynamics of flocs depending on design and hydrodynamic features of the thickener and determine measures to increase productivity and improve process characteristics of thickeners.

Keywords: thickener, flocculation, CFD, PBM.

1. Flocculation

Today chemical reagents, such as flocculants, are widely used in a thickening area of alumina production. The process of flocculation is accompanied by merging of particles of slurry in agglomerates. Solids, integrated in a group, obtain raised settling rate that enables to increase productivity or to improve process characteristic of thickeners.

The result of flocculation is affected by a set of factors such as: properties of particles surface, molecular weight of flocculant, type of flocculant polymeric chain, method of flocculant feeding, properties of liquid phase of suspension and others, but of most importance are intensity and period of mixing of suspension that are investigated in this work

Flocs are essentially complex porous structures consisting of groups of particles. Kranenburg suggested to consider that a floccule consists of similar structures, i.e. is a fractal [1]. The structure of Flocs is characterized by fractal dimension D_f, which does not coincide with dimension of space and can acquire any values from 1 to 3. Values close to 1 correspond to thin thread, D_f =3 value corresponds to a continuous (nonporous) sphere (Figure 1). Introduction of a concept of fractal dimension allowed to connect the size of a floccule with its sedimentation rate.

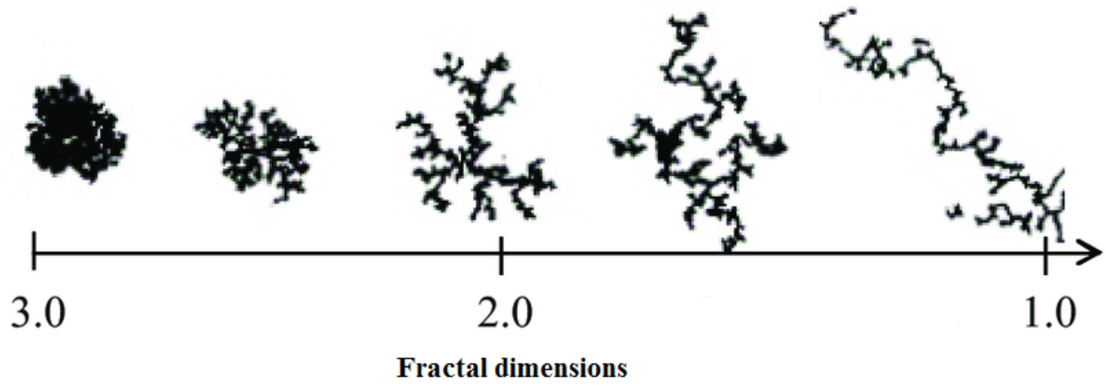

Figure 1. Flocs of various fractal dimension.

2. Settling Rate of Flocs

Settling rate of spherical particles at small Reynolds numbers (Re <0.2) is described by Richardson-Zacky law which considers a factor of particles concentration [2]:

$$V_s = \frac{d_s^2 g(\rho_s - \rho_l)}{18\mu}(1-\varphi)^{4,65} \tag{1}$$

where:

Vs settling rate of spherical particles, m/s
d_s diameter of a particle, m
ρ_s density of particles, kg/m^3
ρ_l density of liquid, kg/m^3
μ dynamic viscosity of liquid, Pa·s
g gravitational acceleration, m/s^2
φ particle volume fraction, m^3/m^3

Taking into account fractal structure of a floccule the law will be transformed to the equation, published in [3]:

$$V_s = \frac{\overline{d_{agg}^2} g(\rho_s - \rho_l) K_p \left(\frac{\overline{d_{agg}}}{d_p}\right)^{D_f-3}}{18\mu}\left(1-\frac{\varphi}{K_p}\left(\frac{\overline{d_{agg}}}{d_p}\right)^{3-D_f}\right)^{4,65} \tag{2}$$

where:

$\overline{d_{agg}}$ average diameter of a floccule, m
$\overline{d_p}$ average diameter of initial particle, n
D_f fractal dimension of a floccule
K_p packing limit

3. Model of Population Balance. Smoluchowski Equation

Flocculation is essentially a process of particles aggregation in flocs accompanied by simultaneous growth and breakage for the account of shear stress in liquid. It is a dynamic process with the rate depending on properties of particles, flocculant and mixing conditions.

Shear stress provides thorough mixing and high probability of collisions between particles and, therefore, rapid growth of flocs. At the beginning of flocculation process particles quickly

6. Conclusion

In the paper, the CFD-PBM method is described and tested for description of dynamics of slurry motion, distribution of a solid phase and kinetics of flocculation in thickening devices, such as: red mud thickeners and washers, sodium carbonate thickeners. Physical simulation of slurry flocculation process of nepheline mud is carried out, a method is proposed for determination of an average size of flocs by means of settling test, setup of parameters of kernel agglomeration and breakage of population balance model of nepheline mud is made enabling to reach an error in determination of average diameter of flocs not exceeding 15%. CFD-PBM method was used in developing a new design of feed well of sodium carbonate thickener at RUSAL Krasnoturyinsk alumina refinery. Simulation of gravitational thickeners by CFD-PBM method makes it possible to determine measures enabling to raise productivity or to improve performance of the device.

7. References

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