Control of particle microstructure in the coating process

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Introduction

Micro– and nano–sized particles are used in coatings for various applications. The properties of some coating films depend critically the features of the particulate microstructure, such as the packing, orientation and binder distribution. Unique functions are possible when monodisperse particles assemble into a crystalline packing or are distributed in a uniform packing. Currently, there are no efficient coating processes that can provide fine control of the microstructure of particulate coatings.

Experiment

In this research, we studied the effect of blade coating on the microstructure of coatings prepared from dispersions of monodisperse particles with diameter of 100 µm by experiment and numerical simulation. Results showed that the structure could be controlled by the gap, the content of water and the speed of the blade. In the case of gaps of 400 ~ 700µm, closed packed

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monolayers partially formed (Fig. 1). For gaps less than 400 μm, close packed structures were not observed. In the last case, the analysis by simulation using Stokesian dynamics showed that some particles were carried away by shear stress and those also depends on the initial conditions of particles and repulsive or attractive forces.

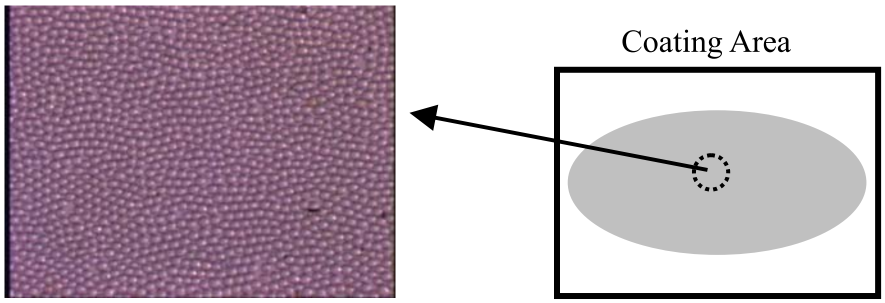

Fig. 1 The structure of particles after blade coating

Simulation by Stokesian dynamics

Stokesian dynamics method was developed by J. F. Brady and G. Bossis. It is the method of dynamically simulating behavior of many particles in a fluid medium. A particle motion is described by coupled n-body Langevin equation:

$$m \cdot \frac{dU}{dt} = F^H + F^P + F^B$$

where F^H, F^P and F^B are the hydrodynamic forces, the deterministic nonhydrodynamic forces and the stochastic forces that are caused by Brownian motion, respectively. The Stokesian dynamics method is a powerful technique for dynamically simulating the behavior of many particles suspended or dispersed in a fluid medium. It can simulate the three-dimensional motion of hydrodynamically interacting particles at low Reynolds numbers. Hydrodynamic interactions are caused as particles move relative to one another and transmit their disturbance to the velocity field through a viscous fluid medium. Since hydrodynamic interactions are dynamic and configuration-dependent, they require recalculation when the particle positions change. Figure.2 shows the sedimentation of three particles calculated by Stokesian dynamics. Each particle was initially located at y = 0, x = -5, 0 and 7 in the fluid medium. These trajectories are very complicated by the hydrodynamics. Dynamics of particles near a single wall are computing using an extension of Stokesian dynamics method that includes far and near-field interactions between particles and wall (Fig. 3).

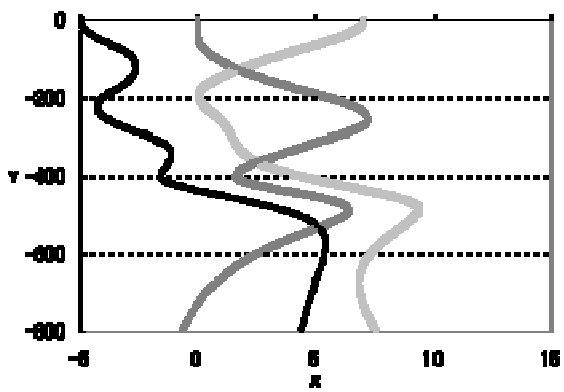

Fig. 2 The sedimentation of three particles

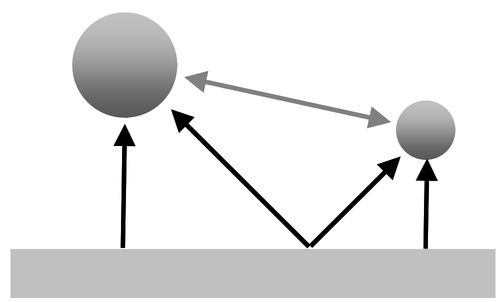

Fig. 3 The interactions between particles and wall

Using this method, the motions of particles in shear flow between two walls were studied instead of the blade and free surface. Periodic conditions were given to horizontal direction. When the distance between particles was small, since lubrication was main force, particles moved slightly (Fig. 4). If repulsive forces are greater than lubrication forces, particles rotated and forces due to hydrodynamics worked upward. When the hydrodynamic force and the repulsive force were greater than the attractive force and gravity, particle came up. Consequently, the structure of particles was changed drastically compared to initial condition (Fig. 5).

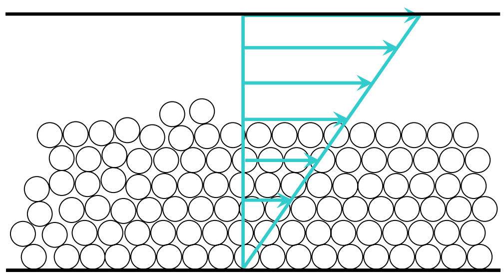

Fig. 4 Simulation of the motion of particles without F^p

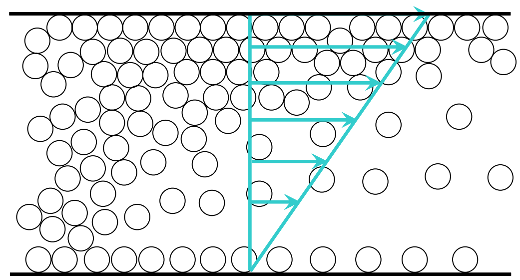

Fig. 5 Simulation of the motion of particles with F^p

Summary

It was verified that Stokesian dynamics method was powerful tool for analyzing particles behaviors in fluid mediums. It can analyze the motions of particles, changing some parameters repulsive, attractive forces. It is useful of particulate coating process.

Acknowledgements

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