Simulation of concentrated suspensions in thin film processing

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Particle-laden flows are important in a wide range of industrial fields, such as oil and gas refinment, paper manufacturing, waste water treatment, biological and polymer processes where transport and manipulation of suspensions occur [1, 2]. In addition, the capability of developing a thin uniform layer of suspensions with evenly distributed particles is essential in many applications. In coating processes of suspensions, the particle distribution pattern can enhance the performance of the final product by changing the bulk and surface characteristics. In this work, the behavior of suspensions in a dip/free coating process is investigated. Specifically, the adherence of a thin film on a substrate surface in vertical withdrawal from a pool of liquid with dispersed solid particles.

In the current study, the dynamics of concentrated suspension flow modeled based on the density of solid particles in the system, where macroscopic methods used for tracking the volume fraction of particles in the flow. In modeling procedure of dispersions in dip coating, a nonlinear constitutive equation of Phillips et al. [3] for the particles distribution in suspensions coupled with Volume of Fluid method [4] for capturing the free surface. The model incorporated into a finite volume method formulation to simulate shear-induced particle migration in non-homogenous shear flows of suspensions in dip coating process.

Numerical simulation enables one to predict the film thickness and validate with experimental results in a range of solid particle volume concentration from 0.1 to 0.4 and withdrawal velocities of 5-15 cm/s. Simulation of free coating for a cylindrical substrate (fiber, wire) in the dispersions can be seen in Fig. 1. In this picture, the solid particles distribution is shown in a dip coating system for the initial volume fraction of 0.4 of particles.

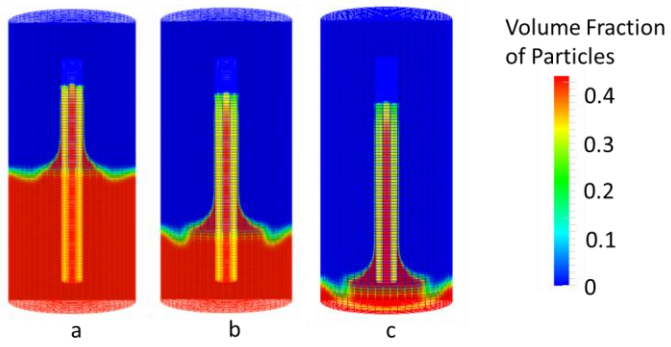

Fig. 1. Dip coating for monodisperse solid particles in the flow – pictures a to c illustrate the simulation of finite length substrate withdrawn out of coating vessel

The numerical simulation for dip coating process has been developed in three dimensions for dispersions and a finite length cylinder has been used as a coating substrate. For this work, the moving mesh method is applied where the substrate and mesh moves with the withdrawal velocity. The zero gradient boundary condition has been set for the base of the coating bath and wall condition with the fixed value of zero velocity has been set for the bath wall. This work investigates a simulation approach to investigate suspension flows and to identify possible limitations and solutions within this simulation methodology.

References

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