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The Research on Two-Phase Dense Suspension

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Abstract. Due to concentrated suspensions for solid dispersed phase and liquid mixture, the diverse nature, so concentrated suspensions of two-phase flow system in the transport process is very complex. Two phase flow is a complex nonlinear dynamic system. In the numerical simulation movement of two-phase flow in the course of the study will be affected by many factors, so flow behavior of concentrated suspensions of two-phase flow will exhibit uncertainty and structure instability. Integrated these factors we have introduced the multi physical quantity numerical simulation software COMSOL, establishes the model to carry on the simulation research.

Introduction

Concentrated suspension is liquid to solid mixtures in many industrial fields use is widely, such as the oil and gas refining, paper, food processing, slurry transportation and waste water treatment, for concentrated suspensions of the research on the development of the industry played a role in promoting. Several different modeling approaches have now been developed to achieve a discrete particle based approach to describing the macroscopic, semi empirical phases. Currently a limited number of solid particle based research methods are appropriate, on the other hand, there are many particles that are better in the phase of the volume fraction of the tracks using a macroscopic average model. So concentrated suspension liquid two-phase flow numerical simulation of must apply the appropriate physical model and the mathematical model to study, the concentrated suspensions and two-phase flow properties are considered, try to overcome the flow behavior of highly irregular, to theoretical calculation and actual results to match.

Model Definition

The model is defined as a mixture system model of solid particles and liquid. The equation to model the momentum transport is

$$\rho\frac{\partial u}{\partial t}+\rho(u\cdot\nabla)u=-\nabla p-\nabla\cdot(\rho c_s(1-c_s)u_{slip}u_{slip})+\nabla[\eta(\nabla u+\nabla u^T)]+\rho g \tag{1}$$

where u is the mass averaged mixture velocity ; p is the pressure; g is the acceleration of gravity; c_s is the dimensionless particle mass fraction; u_{slip} is the relative velocity between the solid and the liquid phases. $\rho=(1-\phi_s)\rho_f+\phi_s\rho_s$ is the mixture density, where ρ_f is the liquid density; ρ_s is the solids density; ϕ_s is the solid-phase volume fraction. η is the mixture viscosity ,

$$\eta=\eta_f(1-\frac{\phi_s}{\phi_{\max}})^{-2.5\phi_{\max}} \tag{2}$$

where η_f is the dynamic viscosity of the pure fluid; $\phi_{\max}$ is the maximum packing concentration.

The mixture model uses the continuity equation,

$$\nabla \cdot u = \frac{\rho_s - \rho_f}{\rho_s \rho_f} (\nabla \cdot J_s) \tag{3}$$

The transport equation for the solid-phase volume fraction is

$$\frac{\partial \phi_s}{\partial t} + \nabla \cdot (\phi_s u) = -\frac{\nabla \cdot J_s}{\rho_s} \tag{4}$$

Where J_s is a particle flux,

$$u_{slip} = \frac{J_s}{\phi_s \rho_s (1 - c_s)} \tag{5}$$

The particle flux J_s is

$$\frac{J_s}{\rho_s} = -[\phi D_\phi \nabla(\dot{\gamma}\phi) + \phi^2 \dot{\gamma} D_\eta \nabla(\ln \eta)] + f_h u_{st} \phi \tag{6}$$

Where u_{st} is the settling velocity of a single particle surrounded by fluid; D_ϕ and D_η are the empirically fitted parameters given by

$$D_\phi = 0.41 a^2$$

$$D_\eta = 0.62 a^2$$

where a is the particle radius .
The shear rate tensor $\dot{\gamma}$ is given by

$$\dot{\gamma} = \sqrt{\frac{1}{2}(4{u_x}^2 + 2(u_y + v_x)^2 + 4{v_y}^2)} \tag{7}$$

The settling velocity u_{st} is given by

$$u_{st} = \frac{2}{9} \frac{a^2(\rho_s - \rho_f)}{\eta_0} g \tag{8}$$

The hindering function f_h defined as

$$f_h = \frac{\eta_f (1 - \phi_{av})}{\eta} \tag{9}$$

Where ϕ_{av} is the average solid phase volume fraction in the suspension; η_f is the dynamic viscosity of the pure fluid; η is the mixture viscosity.

Boundary Conditions

The suspension is placed in a Couette device that is between two concentric cylinders. The inner cylinder rotates while the outer one is fixed. The radii of the two cylinders are 0.64 cm and 2.54 cm, respectively. The inner cylinder rotates at a steady rate of 55 rpm. With the cylinder centered at (0, 0), this corresponds to a velocity of

$$(u, v) = \frac{110\pi}{60}(y, -x)$$

Initial Conditions

There are two different initial particle distributions. In the first example, the particles are evenly distributed within the device. In the second example, the particles are initially gathered at the top of the device. In this case the particles are initially gathered at the top of the device. The particle volume fraction is initially zero in the lower part, while it is 0.59 at the top. Density of particles is 1180kg/m3; Density of pure fluid is 1250 kg/m3; Particle radius is 678 µm; Viscosity of pure fluid is 0.589 Pa•s.

Conclusions

Fig 1 shows the numerically predicted particle concentration at times 0 s, 10 s, 20 s, and 100 s. Initially, the particle motion is dominated by inertia and the effect of the shear-induced migration is not visible. At later times, shear-induced migration causes the particles to move toward the outer boundary. In this case also, the results agree well with the results in Ref. 2.

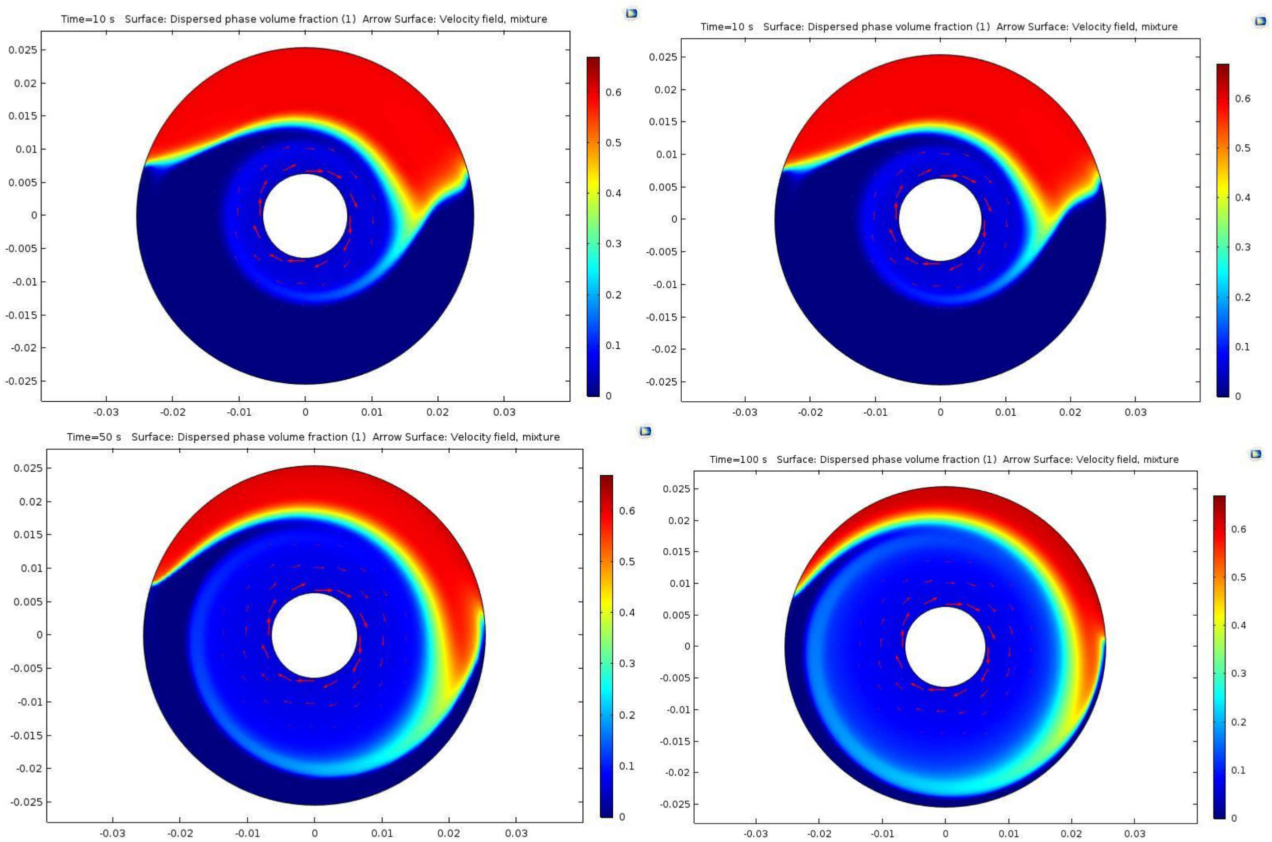

Figure 1. Surface: Dispersed phase volume fraction

Arrow Surface: Velocity field

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