Numerical Viscosity Measurement Method for Solid-Liquid Mixture

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ABSTRACT

It is essential to comprehensively characterize the mechanical behaviour of solid-liquid mixture, when we are concerned with their effects on safety and environmental problems such as scour around seawalls, seabed deformation or erosion of seashore in various fields of coastal, ocean and civil engineering. To reflect the microscopic coupled mechanisms between a fluid and solid particles in the macroscopic flow simulations, this study presents a method of numerical viscosity measurement (NVM) to realize multiscale analysys of solid-liquid mixture. In particular, we originally propose a space-time homogenization procedure for characterizing the macroscopic motions of solid-liquid mixture.

The derived mathematical model enables us to set up two separate governing equations at both macro- and micro-scales. The fluid in the macroscopic governing equation is treated as an equivalent homogeneous medium with average or homogenized viscosity and is regarded as an incompressible Newtonian fluid, whose motion is assumed to be governed by the Navier-Stokes equations. The microscopic equations of the coupling phenomenon of the fluid and solid particles in a certain local domain are solved to determine the microscopic flow fields under adequate boundary and loading conditions.

Then the macroscopic viscosity is determined as the quantity averaged over the microscopic domain and within a certain time interval. This averaging procedure is originally introduced in this study and enables us to realize the NVM. For the analysis corresponding to this NVM, we employ a representative volume element (RVE) whose shape is set as a cylindrical pipe referring to an actual hydraulic measurement with a standard gravimetric capillary viscometer. The Hagen-Poiseuille's law is then utilized to calculate the macroscopic viscosity by using the results of microscopic flow simulations in the RVE.

A set of NVMs is presented to demonstrate that the solid-liquid mixture considered in this study possibly exhibits a non-Newtonian flow characteristics in macroscopic scale. From the obtained results, the effect of microscopic flow properties on the macroscopic viscosity is also investigated. Finally, we conclude that the energy dissipations due to the fluctuations and the frictional loss in micro-scale cause the increase/decrease of the macroscopic viscosity.

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