DFD07-2007-000432
Abstract for an Invited Paper
for the DFD07 Meeting of
the American Physical Society

Unsteady Dynamics of free falling of multi flexible fibers in moderate Reynolds number flows

DEWEI QI, Western Michigan University

The direct simulations of sedimentation of single and multi flexible fibers are conducted in moderate Reynolds number flows by using a newly developed method. In the method, for fluid domain, the lattice Boltzmann equations are used to solve the Navier Stokes equations. For solid domain, a fiber is discretized as a chain of rigid segments. The segments are connected through ball and socket joints and can be bent and twisted. Constraint forces are introduced at each joint. Translation and rotation matrix of fiber are linearized with respect to the constraint forces up to a second order of time step. Thus, motion of the fiber under the constraint and hydrodynamic forces could be solved by using a modified leap-frog algorithm. Effects of many body interaction on fiber fluttering are studied. It is found that in the same conditions initial fluttering may be damped by fluid viscosity for a single flexible fiber while irregular and persistent fluttering, rocking and oscillation may occur for a multi- fiber system. It is evident that clusters, such as doublets and triplets, are spontaneously formed and have a profound impact on unsteady dynamics of fibers. Two mechanisms contribute to an increase in unsteadiness. First the clusters have larger local settling velocity than a single fiber. Second, closely packed fibers become more "fat" or "thick" body and have a lower effective aspect ratio. The flows behind the 'fat' clusters tend to be more unsteady and induce vortex shedding that causes fibers persistently fluttering, rocking or oscillating. It is found that a fiber chain with a long vertical dimension is not stable. They will break down and become more flat structure. This property is directly related to that the fiber is preferentially oriented in horizontal direction due to inertia. In addition, the effects of flexibility on unsteady dynamics of sedimentation of flexible fiber are studied in a given range of Re. We find that when stiffness is very large, the fiber behavior is similar to a stiff or rigid fiber. It receives the largest drag force and results in the smallest average terminal speed. As the fiber stiffness decreases and becomes slightly flexible, a small shape flocculation without reduction of effective fiber length may induce a drag reduction and lead to a terminal speed increase. The mechanism behind the drag reduction is that fiber flexibility changes the wake structures and releases the tip vortexes to some extent. As the stiffness continuously reduces, the fiber becomes more flexible. Both the effective fiber length reduction and shape flocculation contribute to drag reduction and result in the largest terminal speed.