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Motion of a particle in the shear flow near a flat wall

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Abstract

The motion of a small heavy, rigid particle in the shear flow on a stationary wall was investigated in the context of stokes flow. The motion of the particles in the shear flow is easily found in the environment and engineering field. The dispersion of contaminant in the atmosphere and water, peumatic and slurry transport, dust in the respiratory system, fluidized bed combustion, blood flows in the blood vessel are a few examples. It is of great interest to investigate particle motion both in settling environmental problems and designing industrial equipment, by means of experiments and numerical simulations.

The spherical particle that translates parallel to a flat wall experiences a lift force in the direction normal to the wall. It is known that shear-induced lift near a surface may be represented by two components. The first component depends on the relative particle velocity, while the second is due to the solid surface (Ziskind *et* al., 1998). First, the lift force proposed by Saffman(1965) and later modified by Mclaughlin(1991) and Mei(1992) is considered in the prediction of the particle motion without wall. Later, the expression of the lift force was modified to take into account the existence of wall(Cherukat and Mclaughlin, 1994). In this study, the equations of motion are derived from the existing analytical expressions for the hydrodynamic forces of lift accounting for the particle inertia and drag acting on a small particle near a wall. Two components of hydrodynamic drag force were considered. The drag force that was considered by Brenner(1961) is used for acting on a particle that moves toward or away from a plane wall. Goldman *et* al.'s (1967) expression of the drag force is also used for force acting on a particle that moves parallel to the wall.

In the analysis the gravity and buoyancy effect are also taken into account. In a typical gas-particle flow, the ratio of density of the fluid to the density of the particles is of the order of 0.001 or less. The direction of the shear flow was changed to show how the particle moves according to various direction of the shear that occurs in the complex turbulent flow. The analytical solutions for the wall bounded shear flow shows whether the equilibrium state that the particle just moves parallel to the wall exists or not. Analytical and numerical results for the terminal velocities and trajectories of the particle after the enough lapse of the time are presented. This initial value analysis makes it possible to determine whether the particle motion for given flow is stable or moving away from the wall. It is shown that the equilibrium solution of a particle in the unbounded shear flow is stable, irrespective of the initial value. For the wall bounded shear flow, the initial velocity and distance of the particle from the wall may be important factors to determine the motion of the particle. For the numerical analysis the system of equations are solved by the third-order Runge-Kutta method for the both cases, the one without the wall and another with the wall.

Keyword: *heavy particle, shear lift force, stokes flow*

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