The Deviation Characteristics of Sediment Particles in Curvilinear Flows

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ABSTRACT

The direction of sediment motion has been approximately taken to be the same as the flow direction by numerical modelers and researchers. Nevertheless, when the flow is strong and the curvilinear radius is small, such an approximation would induce significant errors in sediment related predictions. The authors built a numerical model with Lagrange method based on particle’s kinematic balance equations to simulate the motion of the sediment particles and their deviation characteristics in a cylindrical container rotated in steady speeds. The influence factors of the sediment particle motion, such as the rotation speed, the diameter and density of the sediment particles were investigated.

KEY WORDS: curvilinear flow; sediment particle; deviation angle; trajectory; particle size; particle density; sediment separation

INTRODUCTION

The sediment particles don’t follow the trails of fluid cells in a curvilinear flow because they have different inertia. On a flat seabed or riverbed, the migration directions of a sediment particle and a local fluid cell are different, and the motion radius of the sediment particle is larger than that of the fluid cell in the curvilinear flow. Under curvilinear flow circumstances, the deviation characteristics of sediment particles away from the surrounding fluid are still not crystal clear. The direction of sediment motion has been approximately taken to be the same as the flow direction by numerical modelers and researchers. Nevertheless, when the flow is strong or the curvilinear radius is small, such an approximation would induce significant errors in sediment related predictions, for instances, scouring predictions around underwater pipelines and bridge piers, simulation of the sediment motion and the inner wall erosion in sludge pumps, etc.

The knowledge of the mechanics and dynamics of sediment particles in the impeller pump is the most important for the two-phase flow pump research, and makes great sense to pump designs. In two-phase flow pumps, the diameter, density, and rigidity as well as other features of the sediment particle influence the pump’s both hydrodynamic performance and wearable resistance (Xu, et al. 1994). The motion trajectories and rules of sediment particles in dilute flow in centrifugal pumps were studied by means of slow-motion technology and particle trajectory simulation (Xu, et al.1992, 1993; Liu, et al. 2008a, 2008b). It was concluded that in situations of big mass particle and high angular velocity, particles tend to approach the impellers’ high-pressure side and then wear off it more easily. The hydrodynamic performances and wear-abilities of new designed slurry pumps were improved with the help of analysis results of particle’s motion trajectories (Chen, et al. 1999).

In solid separation machines like hydrocyclones, the deviation characteristics of dispersed particles dominate their work efficiencies. Wang et al. (2006) investigated the two-phase flow inside the separation machines. Based on analysis of the forces acted on the sediment particles in the hydrocyclones, he concluded that particle’s capability to move with water flow was related to their density, diameter and other features. They also applied stochastic trajectory models to simulate the sediment particles’ motion and analyzed the impacts of particle’s diameter, initial position and hydrodynamic characteristics on its deviation characteristics (Wang, et al. 2006).

Inside the bowed pipes of a slurry transportation system, the particles’ motion characteristics in the curvilinear flow directly influence the transport efficiency and the wear and tear of the pipes. In a curved open-channel, the motion characteristics of particles not only influence the erosion to the banks as well as the development of troughs and floodplains, but also determine the river’s wriggling direction. On the other hand, ordinary two-phase numerical models do not take the deviation process into account to simulate the transport of bed load or suspended load. Although few models noted the direction difference between the flow and the particle motion, the particles’ inertia is still ignored (Xia and Wang 2002).

In a steady curvilinear flow, the velocity and curvature radius of arbitrary flow cell vary with its position in a very complicated manner.