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A particle–particle Reynolds stress transportation model of swirling particle-laden-mixtures turbulent flows

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ABSTRACT

On the basis of the gas–particle Euler–Euler two-fluid approach, a new particle–particle Reynolds stress transportation model is proposed for closing the constitution equations of particle-laden-mixtures turbulent flows. In this model, binary particle-particle interaction originating from large-scale particle turbulent diffusions are fully considered in view of an extension closure idea of second-order-moment disperse gas–particle turbulent flows. The binary-particles turbulent flows with different density and same diameter are numerically simulated. The number density, the time-averaged velocity, the fluctuation velocity, the multiphase fluctuation velocity correlations, the normal and the shear Reynolds stress are obtained. Simulated results are in good agreement with experimental data. Binary mixture system has a unique transportation behavior with a stronger anisotropy due to particle inertia and multiphase turbulence diffusions. Fluctuation velocity correlation of axial–axial gas–particle is about twice larger than those of axial–axial particle–particle interaction. Moreover, both normal and shear Reynolds stress are redistributed.

1. Introduction

A better understanding of the gas–particle turbulent flow behaviors is of great importance for improving facility efficiency. They can be achieved by mathematical model and numerical simulation technology. As we known that Euler–Lagrangian discrete particle model [1–12] Euler–Euler two-fluid continuum model [13–21] are often used to simulate the gas–particle flows. Two-fluid model considers both gas and particle phase to be continuously and fully interpenetrated. Owing to the continuum representation of particle phases, an additional closure law is required to be described the rheology of particles [13–15]. With respect to the dilute gas–particle flows, particle–particle collisions are neglected. On the basis of second-order-moment methods, a series of second-order-moment two-phase turbulence model [16–21]. They are called by k–ε–Ap model, where Ap is the algebraic particle turbulence model based on the particle-tracking-fluid concept, is used to simulate strongly swirling gas–particle flows in cyclone combustor. Simulated results of the particle concentration and the particle velocity are not well in agreement with measured data. The k–ε–k_p model is successfully used for swirling gas–particle flows in sudden-expansion chamber. The predicted axial and tangential two-phase velocity and particle mass flux are in good agreement with phase doppler particle anemometer (PDPA) measurement data. The unified second-order-moment (USM) model and improved SGS (SGS-USM) model are performed to simulate swirling flows with a qualitatively anisotropy of two-phase that cannot be simulated by above mentioned models. According to the isotropic turbulence kinetic energy of scalar quantity, a correlation transportation equation on gas–particle fluctuation velocity correlation is established [22]. Its problems is that the closed transportation equation cannot reflect the anisotropic turbulence flows. At the same time, closure of probability-density-function (PDF) transport equations has been established and developed [23–28].

The majority of industrial interest focuses on particle segregation or particle mixing system due to different particle size or density. Hydrodynamic behavior of mixture or segregation system is entirely different from mono-disperse particle system. As for dense gas–particle flows in the framework of Euler–Euler two-fluid model, a model for binary mixture of particles is proposed [29]. The assumption is that two kinds of particles in mixture have the same granular temperature. The shortcoming of this model is that this model cannot consider the dissipation

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