Effect of Parcel Models on particles' dispersion and gas-particle two-phase interaction in a particle-laden turbulent mixing layer

Masaya MUTO*, Hiroaki WATANABE
Central Research Institute of Electric Power Industry, 2-6-1 Nagasaka, Yokosuka, Kanagawa, Japan
masayam@criepi.denken.or.jp and whiroaki@criepi.denken.or.jp

Abstract

Particle-laden turbulent flows are encountered in a number of engineering applications such as energy conversion and propulsive devices using solid or liquid fuel. Therefore it is great importance to understand the effects of laden particles on turbulence and the diffusivity of particles in turbulent flow fields. In most practical particle-laden turbulent flows, the volume fraction of the dispersed particle is small, so that inter-particle collisions are often negligible. On the other hand, the particle mass fraction often becomes large owing to a large density ratio of solid or liquid particle to ambient gas, hence the modulation of flow field by particles cannot be neglected. Consequently, momentum exchange between two phases needs to be considered. In the traditional approach for particle-laden flow computation, the Eulerian equations for gaseous phase are solved along with a Lagrangean model for particle transport. However, tracing every particle in Lagrangean manner is still difficult for practical purpose because the number of particles in most engineering applications is huge. Therefore a parcel model is generally employed in the Eulerian-Lagrangean numerical procedures to reduce computational cost.

In the parcel model, a certain number of particles are represented by one parcel and the parcels are traced in flow field instead of each particle. Here we can consider two types of parcel model. The first model is that each parcel has the same volume, which is generally used in commercial software on gas-particle two-phase flow. In this model the smaller particle diameter becomes, the larger the number of particles is represented by one parcel. Another model is that each parcel represents the same number of particles. In this model the smaller the particle diameter becomes, the more the number of parcels increases. Both models have been used in existing studies but few reports on a difference between two models exist. So in this study, effect of parcel models on particles' dispersion and two-phase interaction is investigated. To validate both models, a base case in which parcel model is not applied is also implemented as a reference.

A three-dimensional DNS is performed in a particle-laden turbulent flow to investigate particles spatial dispersion, exchange of momentum, and interphase mass transfer which is represented by nonreactive scalar distribution yield from dispersed particles, are investigated in a turbulent mixing layer. In this study, neither inter-particle collision nor particle breakup is considered. The statistical results show that in former stage of the mixing layer parcel models do not affect particle dispersion so much compared to the reference case. However, the latter stage of the mixing layer the former parcel model causes a spatially skewed distribution of particles and low dispersivity compared to the reference case. This is because that a number of particles with small diameter, which are considered to be diffusive, are represented by small number of parcels in this model. Therefore a diffusion of the small number of parcels causes the skewed distribution of particles. Subsequently scalar distribution is also skewed. In the same stage of the mixing layer it is found in comparing with reference case that the latter parcel model shows better reproducibility than the former model. However, particle, momentum and scalar distributions are not smoothly distributed locally because of the discrete parcel appearance spatially. Finally, characteristics of different two parcel models are clarified.

* Corresponding author: masayam@criepi.denken.or.jp