Editorial

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Numerical study on super/hypersonic flow, mixing, and combustion phenomena, 2015

Prediction of super/hypersonic flow transition, modeling of two-phase compressible fluids, and turbulence closures are challenging problems in fluid mechanics. It is also of great importance to understand high-speed compressible complex flow physics and hence develop reliable engineering models for obtaining accurate performance prediction of high-speed aircrafts and propulsion devices. Therefore, six papers are selected in the Special Issue of 2015, of which either report the recent research on the super/hypersonic flow and mixing phenomena by means of numerical simulation, or present numerical methodology and mathematical models in computation of compressible two-phase flows. We should address the amount of recent researches on supersonic flow mixing and combustion carried out experimentally, although not included in this issue, which definitely promotes the research on numerical simulation and developments of mathematical models.

As known, reducing friction resistance and aerodynamic heating has important engineering significance to improve the performances of super/hypersonic aircraft. One paper of the issue performs the investigation about the influences of wall cooling and suction on the transition process. The authors use the large eddy simulation to compute the supersonic boundary layer spatial transition over a flat-plate with freestream Mach number 4.5 at different wall temperature and suction intensity. The wall cooling and suction are capable of changing the mean velocity profile within the boundary layer and improving the stability of the flow field, thus delaying the onset of the spatial transition process. The transition control will become more effective as the wall temperature decreases, while there is an optimal wall suction intensity under the given conditions. Moreover, the development of large-scale coherent structures can be suppressed effectively via wall cooling, but wall suction has no influence.

Turbulence closures considering flow compressibility corrections are conductive to predict wall friction and heat fluxes accurately. One paper in this issue investigates the applications of pressure work, pressure-dilatation and dilatation-dissipation corrections to turbulence models in simulations of hypersonic flat boundary layer flows. The pressure work and pressure-dilatation models yield the better results. Among the three dilatation-dissipation models, Sarkar and Wilcox corrections present larger deviations from the experiment measurement, while Zeman correction can achieve acceptable results. Density-corrected model by Catris and Aupoix is suitable for shock wave/boundary layer interaction flows which can improve the simulation accuracy of the peak heating and have a little influence on separation zone.

Three papers of this issue concern two-phase flow dynamics under the condition of supersonic flow. The first one presents spray droplets transports representing transverse liquid jet to a supersonic crossflow. The authors establish a pure two-fluid model and solve a well-posedness problem of the droplet phase governing equations by applying an equation of state in the kinetic theory. It is shown that the prediction of penetration height is in agreement with the empirical correlations. The second paper compared three stochastic separated flow (SSF) models, the motivation of which is to evaluate the model capability for predicting dispersion of inertial particles in supersonic turbulent flows. In the study, they consider the correction of flow compressibility taking Clift's expression as the drag force model. Three models can well predict the mean velocities of the particle phase. The particle dispersion is over-predicted by the conventional SSF model in the supersonic particle-laden boundary layer flow, while the improved SSF model is less predictable for the particle spatial distribution in the particle-laden strut-injection flow. The third paper investigates the response of dispersed droplets to oblique shock waves in the supersonic mixing layer using the large eddy simulation coupled with the particle Lagrangian tracking model. They show that small- and medium-sized droplets remain their preferential distribution in the vortices after crossing the shock wave, while large-sized droplet become more dispersed. Compared with the aerodynamic response, the thermal response of droplets is slower, especially under the impaction of the shock wave.

One paper carries out a direct numerical simulation study of the characteristics of macroscopic and microscopic rotating motions in swirling jets. It is found that the vortex cores of low-swirl flows are of regular cylindrical-helix patterns, whereas those of the high-swirl flows are characterized by the formation of the bubble-type vortex breakdown followed by the radiant processing vortex cores. The effects of macroscopic and microscopic rotating motions with respect to the mean and fluctuation fields of the swirling flows are also evaluated in the paper.

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