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Concentration of Droplets in a Transient Gas Flow

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Abstract : The calculation of the concentration of inertial droplets in complex flows is encountered in the modelling of numerous engineering and environmental phenomena; for example, fuel droplets in internal combustion engines and airborne pollutant particles. The results of recent research, focused on the development of methods for calculating concentration and their implementation in the commercial CFD code, ANSYS Fluent, is presented here. The study is motivated by the investigation of the mixture preparation processes in internal combustion engines with direct injection of fuel sprays. Two methods are used in our analysis; the Fully Lagrangian method (also known as the Osiptsov method) and the Eulerian approach. The Osiptsov method predicts droplet concentrations along path lines by solving the equations for the components of the Jacobian of the Eulerian-Lagrangian transformation. This method significantly decreases the computational requirements as it does not require counting of large numbers of tracked droplets as in the case of the conventional Lagrangian approach. In the Eulerian approach the average droplet velocity is expressed as a function of the carrier phase velocity as an expansion over the droplet response time and transport equation can be solved in the Eulerian form. The advantage of the method is that droplet velocity can be found without solving additional partial differential equations for the droplet velocity field. The predictions from the two approaches were compared in the analysis of the problem of a dilute gas-droplet flow around an infinitely long, circular cylinder. The concentrations of inertial droplets, with Stokes numbers of 0.05, 0.1, 0.2, in steady-state and transient laminar flow conditions, were determined at various Reynolds numbers. In the steady-state case, flows with Reynolds numbers of 1, 10, and 100 were investigated. It has been shown that the results predicted using both methods are almost identical at small Reynolds and Stokes numbers. For larger values of these numbers (Stokes — 0.1, 0.2; Reynolds — 10, 100) the Eulerian approach predicted a wider spread in concentration in the perturbations caused by the cylinder that can be attributed to the averaged droplet velocity field. The transient droplet flow case was investigated for a Reynolds number of 200. Both methods predicted a high droplet concentration in the zones of high strain rate and low concentrations in zones of high vorticity. The maxima of droplet concentration predicted by the Osiptsov method was up to two orders of magnitude greater than that predicted by the Eulerian method; a significant variation for an approach widely used in engineering applications. Based on the results of these comparisons, the Osiptsov method has resulted in a more precise description of the local properties of the inertial droplet flow. The method has been applied to the analysis of the results of experimental observations of a liquid gasoline spray at representative fuel injection pressure conditions. The preliminary results show good qualitative agreement between the predictions of the model and experimental data.

Keywords : internal combustion engines, Eulerian approach, fully Lagrangian approach, gasoline fuel sprays, droplets and particle concentrations
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