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Analysis of the Homogeneous Turbulence Structure in Uniformly Sheared Bubbly Flow Using First and Second Order Turbulence Closures

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Abstract : The presence of the dispersed phase in gas-liquid bubbly flow considerably alters the liquid turbulence. The bubbles induce turbulent fluctuations that enhance the global liquid turbulence level and alter the mechanisms of turbulence. RANS modeling of uniformly sheared flows on an isolated sphere centered in a control volume is performed using first and second order turbulence closures. The sphere is placed in the production-dissipation equilibrium zone where the liquid velocity is set equal to the relative velocity of the bubbles. The void fraction is determined by the ratio between the sphere volume and the control volume. The analysis of the turbulence statistics on the control volume provides numerical results that are interpreted with regard to the effect of the bubbles wakes on the turbulence structure in uniformly sheared bubbly flow. We assumed for this purpose that at low void fraction where there is no hydrodynamic interaction between the bubbles, the single-phase flow simulation on an isolated sphere is representative on statistical average of a sphere network. The numerical simulations were firstly validated against the experimental data of bubbly homogeneous turbulence with constant shear and then extended to produce numerical results for a wide range of shear rates from 0 to 10 s^-1. These results are compared with our turbulence closure proposed for gas-liquid bubbly flows. In this closure, the turbulent stress tensor in the liquid is split into a turbulent dissipative part produced by the gradient of the mean velocity which also contains the turbulence generated in the bubble wakes and a pseudo-turbulent non-dissipative part induced by the bubbles displacements. Each part is determined by a specific transport equation. The simulations of uniformly sheared flows on an isolated sphere reproduce the mechanisms related to the turbulent part, and the numerical results are in perfect accordance with the modeling of the transport equation of the turbulent part. The reduction of second order turbulence closure provides a description of the modification of turbulence structure by the bubbles presence using a dimensionless number expressed in terms of two-time scales characterizing the turbulence induced by the shear and that induced by bubbles displacements. The numerical simulations carried out in the framework of a comprehensive analysis reproduce particularly the attenuation of the turbulent friction showed in the experimental results of bubbly homogeneous turbulence subjected to a constant shear.

Keywords : gas-liquid bubbly flows, homogeneous turbulence, turbulence closure, uniform shear
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