Numerical study on a turbulent bubbly pipe flow

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We perform a direct numerical simulation of an air-water monodispersed turbulent bubbly pipe flow to investigate the turbulence characteristics and propose a two-phase RANS model based on the observation. The liquid bulk and bubble Reynolds numbers are 5300 and 500-1000, respectively, based on the pipe diameter, bulk velocity, bubble diameter, and relative mean bubble velocity. At these Reynolds numbers, bubble-induced agitation suppresses shear-induced turbulence. The root-mean-square velocity fluctuations are proportional to $\bar{\psi}^{0.4}$ at all radial locations including near the wall (Fig. 1(a)), where $\bar{\psi}$ (r) is the mean bubble volume fraction. This result agrees with the previous finding[1] from rising bubbles in quiescent water, where liquid fluctuation thoroughly came from bubble-induced agitation. Most of the previous two-phase RANS models included the effect of the bubble-induced agitation in addition to the existing single-phase RANS models[2]. However, these models cannot fully describe the interaction between the shear-induced turbulence and bubble-induced agitation. We modify the algebraic two-phase RANS model[3] considering this relation, and show that our modified model outperforms the original model for a wide range of the liquid bulk Reynolds numbers (Fig. 1(b)).

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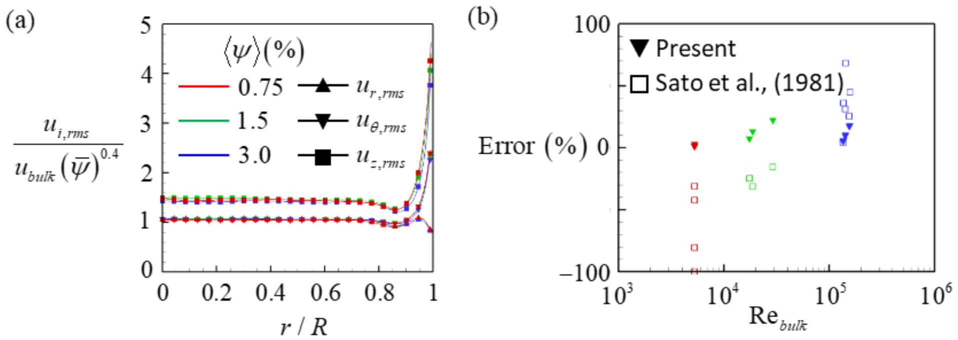

Figure 1: (a) Rms velocity fluctuation profiles with different bubble volume fractions. (b) Skin friction error obtained by the algebraic RANS models: red colour (present DNS data); green colour (data from Sato[3]); blue colour (data from Liu[4]).