Available online at www.sciencedirect.com
ScienceDirect
Journal of Hydrodynamics
2011,23(3):282-288
DOI: 10.1016/S1001-6058(10)60114-X
www.sciencedirect.com/science/journal/10016058

DIRECT NUMERICAL SIMULATIONS OF TURBULENT CHANNEL FLOWS WITH CONSIDERATION OF THE BUOYANCY EFFECT OF THE BUBBLE PHASE*

LIU Nan-sheng, CHENG Bao-guo
Department of Modern Mechanics, University of Science and Technology of China, Hefei 230026, China,
E-mail: lns@ustc.edu.cn
QUE Xia
Department of Computer Science and Technology, Hefei University of Technology, Hefei 230009, China
LU Xi-yun
Department of Modern Mechanics, University of Science and Technology of China, Hefei 230026, China

(Received December 5, 2010, Revised April 6, 2011)

Abstract: Turbulent channel flows with consideration of the buoyancy effect of the bubble phase is investigated by means of the Direct Numerical Simulation (DNS). This two-phase system is solved by a two-way coupling Lagrangian-Eulerian approach. The Reynolds number based on the friction velocity and the half-width of the channel is 194, and the gravitational acceleration varies from −0.5 to 0.5, ranging from the upflow to the downflow cases. This study aims to reveal the influence of buoyancy on the turbulence behavior and the bubble motion. Some typical statistical quantities, including the averaged velocities and velocity fluctuations for the fluid and bubble phases, as well as the flow structures of the turbulence fluctuations, are analyzed.

Key words: Direct Numerical Simulations (DNS), turbulent bubbly flow, upflow/downflow, turbulence fluctuations, bubble statistics, turbulence structures

Introduction

Two-phase bubbly turbulent flows are widely found in various industrial applications, such as oil wells, boilers, nuclear reactors, and airlift pumps. In all these applications, the complex bubble motions have a great influence on overall heat, momentum and mass transfer, and play a crucial role in the efficiency and safety of these facilities. To better understand the dynamics of the turbulent bubbly flows, a number of investigations were carried out[1-5]. It is found that the buoyancy induced by the gravity combined with the lift force dominates the bubble dispersion in the wall region for the turbulent bubbly upflows and downflows[6-8].

The preferential bubble concentration is observed in turbulent channel flows laden with air bubbles, which indicates that bubbles are driven to the wall in the upward flow and away from the wall in the downward flow[7]. This mechanism of the preferential bubble distribution is related to the driving action of the quasi-streamwise vortices in the wall layer and the buoyancy induced by the gravity and lift force[8]. Several numerical simulations were performed to reveal quantitatively the role of the lift force acting on the bubbles and inducing their preferential distribution[6-8], but the influence of buoyancy of the bubble phase on the turbulence behavior and the resultant bubble motion, and their interactions remain not well studied, which motivates the present study of the buoyancy effect of the bubble phase in the turbulent bubbly upflows and downflows by the Direct Numerical Simulation (DNS).

It is well established that the direct numerical

* Project supported by the National Natural Science Foundation of China (Grant Nos. 10772173, 10972211 and 11072236), the Fundamental Research Funds for the Central Universities and the Science and Technology Innovation Foundation of the Chinese Academy of Sciences (Grant No. CXJJ-11-M69).

Biography: LIU Nan-sheng (1975-), Male, Ph. D., Associate Professor