Two-way coupling in a diffusive gas-particles turbulence: settling velocity and turbulence modification

L. Vignal[1], V. Roig[1], L. Ben[1], J. Borée[2]

1: Institut de Mécanique des Fluides de Toulouse, UMR 5502 CNRS-INPT-UPS, laure.vignal@hmg.inpg.fr, roig@imft.fr, livier.ben@free.fr

2: Laboratoire d'Etudes Aérodynamiques, ENSMA Poitiers, France, jacques.boree@lea.ensma.fr

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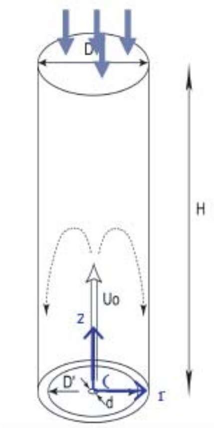
This paper describes experiments on the behavior of heavy particles in a stationary diffusive air turbulence. The experimental apparatus consists in a vertical jet confined in a tube closed at the top section, from where particles are injected uniformly (figure 1). In the single-phase case, at some distance from the nozzle (z/D>4.3) a turbulent region develops where turbulence is transported by turbulent diffusion. It is a non homogeneous flow (figures 2 and 3) which has specific features: exponential decay of the various moments of the velocity, constant integral scale, isotropy and transverse homogeneity of the Reynolds stress tensor (Risso & Fabre, 1997). In the present two-phase flow study, we analyze the interaction between the two phases in this region. The range of Stokes numbers allows generation of clusters by preferential concentration (Eaton et al. 1994 for a review). We have developed a PIV /PTV 2D2C methodology similar to the one of Khalitov & Longmire (2002) in order to measure simultaneously the velocity fields of both phases. We acquire images with simultaneous presence of particles (40-50Cm) and tracers (1-3Cm). By thresholding technique we separate them to generate two different images adequate respectively for PIV and PTV image processing. We have used a PIV algorithm with an iterative multigrid method with cell shifting and deformation (Maurel, 2001). We have carefully chosen optimal parameters for PIV (ratio between mesh size and particle diameter, particle concentration…) to obtain accurate measurements in two-phase flow (Vignal et al., 2004-a). We have developed and validated a new algorithm for PTV that allows particle velocity measurements in dense groups of particles based on Keane et al. (1995) and Stellmacher et al. (2000). The interactions between both phase results in a strong modification of the turbulence even if the volume fraction of the particles is low (figure 3). The level of the turbulence is enhanced and the anisotropy is increased. We discuss the origin of such a modification by an analysis of the heterogeneity of the particle concentration field. Preferential concentration is proved to be a dominant effect present in the upper part of the tube. We have qualitatively explored the spatial and temporal scales associated to the clusters of particles. We then discuss the collective effects of the particles on turbulence as a cluster density effect, with a phenomenological model similar to the model used by Aliseda et al. (2002). This phenomenological model is in very good agreement with our measurements.



Injection of particles

Fig. 1 Scheme of the experimental set-up.

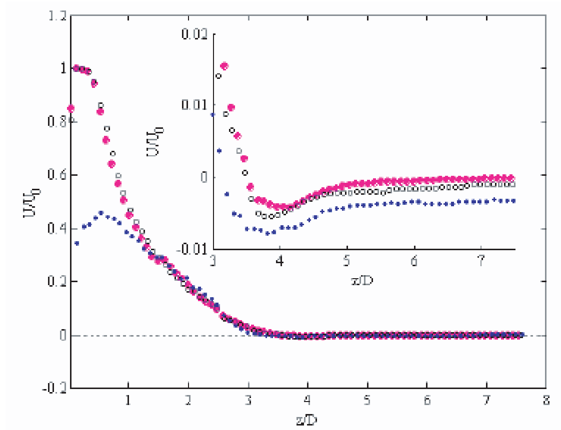


Fig. 2 Evolution of the longitudinal mean velocities along the axis of the tube ● : single-phase flow o : two-phase flow, gas ; ● : particles

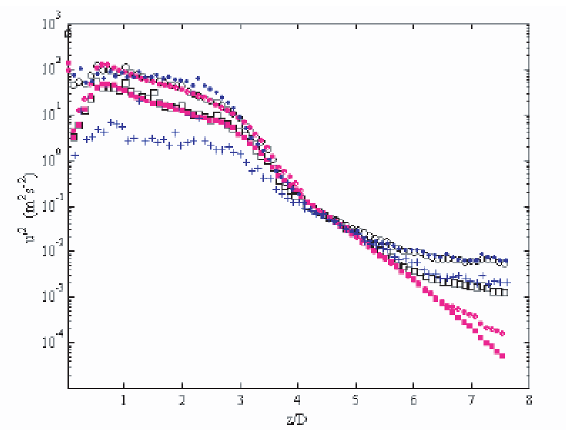


Fig. 3 Evolution of longitudinal (F, •) & transversal (H, +) 2d order moments of the velocity along the axis (Noticeable modification of turbulence for z/D>5) F, H: single-phase flow; J, K: two-phase flow, gas ; •, +: particle.