EXAMINATION OF TWO PARTICLE DISPERSION MODELS IN THE LIMIT OF LOW PARTICLE INERTIA

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Abstract The purpose of this contribution is to examine particle dispersion stochastic models in the limit of low particle inertia. Two different stochastic models previously used to model the fluctuating fluid velocity seen by particles are considered. The first one is the GLM-type model proposed by Arcen and Tanière (2009) and used to predict the dispersion of inertial particles in a turbulent channel flow. The second one is a normalized-type model given by Bocksell and E. Loth (2006) which was used to predict particle dispersion in a turbulent boundary layer. For both models, it was shown that they verify the law of mass conservation in the limit of low particle inertia (tracer-limit particle). This is one of the criteria that inertial particle dispersion models have to respect. Nonetheless, it was not proved that they can model correctly second-order moments of the velocity in the tracer-limit case. In the present study, we show that both models used with parameters extracted from DNS data are able to predict accurately these statistics.

INTRODUCTION

The transport of inertial particles in a turbulent flow is usually described using the point-force approximation. In this framework, the equation of motion of the each particle can be then solved if the instantaneous fluid velocity at particle location (also known as the fluid velocity seen by particles) is known. Nowadays, different methods can be used to properly determine this velocity. The first one is Direct Numerical Simulation (DNS). It gives the most accurate estimation of the fluid velocity seen by particles. Nonetheless, it necessitates high computational resources, thus this approach is not tractable for high Reynolds number particle-laden flows yet. When the computational cost of the DNS technique is too high, macroscopic numerical simulation such as Reynolds-averaged Navier-Stokes (RANS) can be considered. To predict the motion of solid particles in a turbulent flow using a RANS method, the random nature of the velocity along inertial particle trajectories has to be reconstructed since only mean quantities (such as the mean velocity and some of the mean turbulent characteristics) of the carrier phase are given by the RANS method. Several stochastic models (particle dispersion models) have been previously proposed in order to predict the fluid velocity along particle trajectories. In the present study, we focus on two of them. The first one was given by Arcen and Tanière (2009) and is based on the Generalized Langevin Model (GLM) proposed by Pope (1983) to model the motion of fluid particles in turbulent flows. The second model was proposed by Bocksell and Loth (2006) and belongs to the family of normalized-type stochastic models. This latter model can be seen as an extension of the one proposed by Wilson, Turtell and Kidd (1981) to track fluid particles in non-homogeneous turbulent flows. The aim of the present study is to test the performance of both models in the case of the tracer limit. By this way, we can check that both models reduce correctly to a fluid model. Such a situation is fundamental since possible inconsistencies between the velocity statistics extracted from DNS (Eulerian point of view) and from stochastic simulation (Lagrangian point of view) can be emphasized.

PERFORMANCE OF SOME DISPERSION MODELS IN THE LIMIT OF LOW PARTICLE INERTIA

In order to assess the performance and the physical relevance of the stochastic models, we performed simulations of the motion of fluid particles in a turbulent channel flow at Reynolds number based on the wall-shear velocity and half-width equals to $Re_\tau \approx 155$. To perform the test, the channel was divided in the wall-normal direction into 40 slabs and 10 000 fluid particles were initially located in each slab. These particles were then tracked according during $t^+ = 500$ (superscript "+" denotes quantities expressed in wall units). The velocity along the trajectory of each particle was computed using the GLM model or the normalized model proposed by Bocksell and E. Loth (2006). The parameters for each model are provided by means of DNS data. The configuration as well as the numerical methods of the DNS can be found in Marchioli *et al.* (2008).

In figure 1, we present the root mean square of velocity given by DNS and by the Lagrangian simulation using the GLM. It can be seen that the streamwise ($i = 1$), wall-normal ($i = 2$), and spanwise ($i = 3$) velocity rms are very well predicted by the GLM model whatever the wall-normal coordinate y^+. The comparison with the results given by the normalized model of Bocksell and E. Loth (2006) is shown in figure 2. A very good accordance with the DNS data is also obtained. This shows that both stochastic models can provide consistent and physical results.

In the full-length presentation, fluid particle concentration, Reynolds shear stress, and triple velocity correlations, will be also given for the GLM and normalized model proposed by Bocksell and E. Loth (2006) in order to the thoroughly assess the performance of both stochastic models.

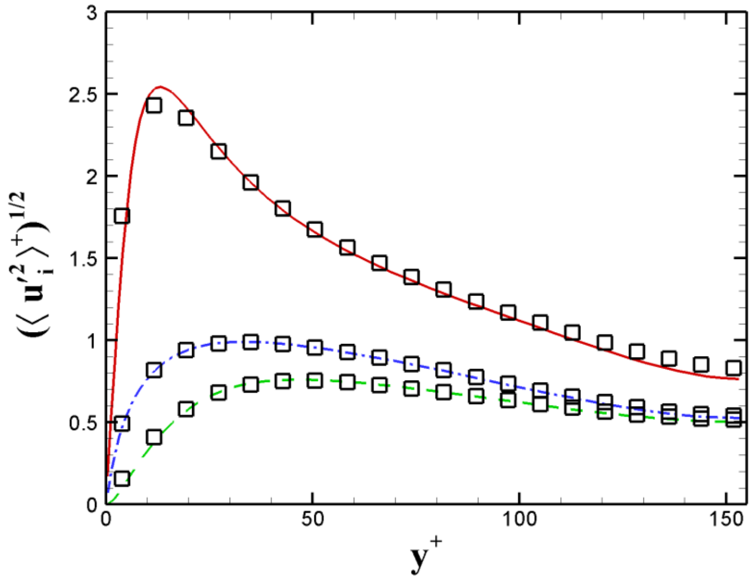

Figure 1. Velocity root mean square. Lines : DNS data for the streamwise (—), wall-normal (– – –), and spanwise (– · –) components. Symbols are the results given by the GLM stochastic model.

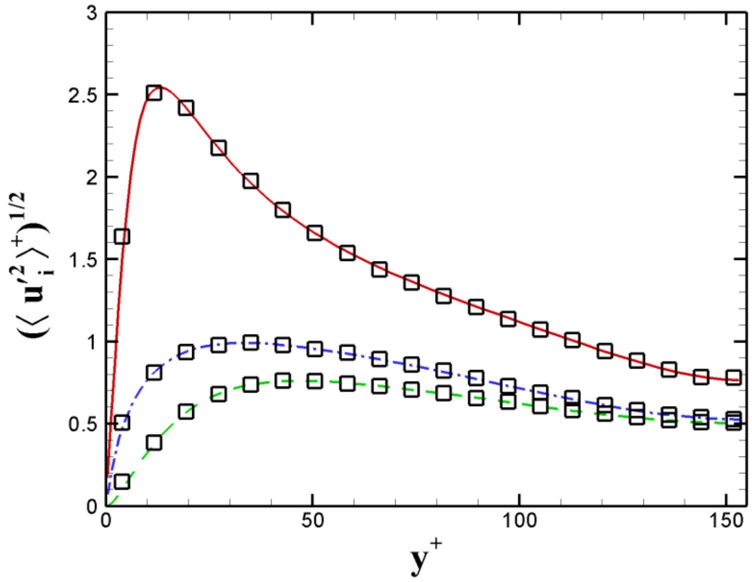

Figure 2. Velocity root mean square. Lines : DNS data for the streamwise (—), wall-normal (– – –), and spanwise (– · –) components. Symbols are the results given by the normalized stochastic model [2].

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