DNS of particle-laden turbulent channel flow

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1. MOTIVATION:

Turbulent particle dispersion in boundary layers is a fundamental issue in a number of industrial and environmental applications. DNS and Lagrangian tracking of particles may be an useful tool to provide physical insights, new modelling ideas and benchmark cases. Despite the relative large number of published work, however, there is no clear consensus on some fundamental features of the phenomenon. This lack of consensus may be due to the large number of parameters involved (physical and computational).

Physical parameters include, among others:
- fluid-particle interaction (one-way/two-way coupling);
- particle-particle interaction (collision models);
- particle-wall interaction (reflecting/absorbing wall, wall effects);
- particle rotation;
- external forces acting on particles (modelling of lift force, ...);

Computational/numerical parameters include, among others:
- performance of different computer codes (*viz.* numerical method of the flow solver: pseudospectral, FD, ...);
- fluid velocity interpolation scheme;
- grid resolution;

The objectives of this benchmark calculation are to have a large number of people working on the same specific problem and to establish a validated DNS dataset including :
- reliable and accurate velocity statistics for the fluid field, the particle field and the fluid field at the particle position (mean and rms velocities, skewness and flatness, Reynolds stresses and quadrant analysis);
- particle concentration profiles and deposition rates;
- one-particle statistics (particle velocity auto-correlations, particle turbulent diffusivity, particle mean-square displacements, Lagrangian integral time scales);
- two-particle statistics (rms particle dispersion).

To these objectives, sinchronized activity among participants are required.

2. GUIDELINES FOR PARTICIPANTS:

Participants are asked to fulfill the following steps:
- Reproduce the 1-way coupling DNS of particle-laden turbulent channel flow using data provided in Section 3 and including only drag and inertia in the particle equation of motion. This is the required preliminary *benchmark simulation* (BS), which must be run by all participants. A brief documentation about the numerical scheme and the boundary conditions used for the computations should be prepared at this step.
- Include into the BS one or more additional simulation parameters. To compare results more easily, the choice will be restricted to physical simulation parameters, with specific focus on fluid-particle two-way coupling, inter-particle collisions and lift force models (details about modelling issues may be retrieved from the references listed in Section 3.3). Further parameter analysis will be planned at a later stage.
  Note: additional simulation parameters should be included into the BS one at a time.
- Build a thorough statistical framework to single out the effect of each additional simulation parameter from macroscopic particle behavior.

3. PARAMETERS OF THE BENCHMARK SIMULATION:

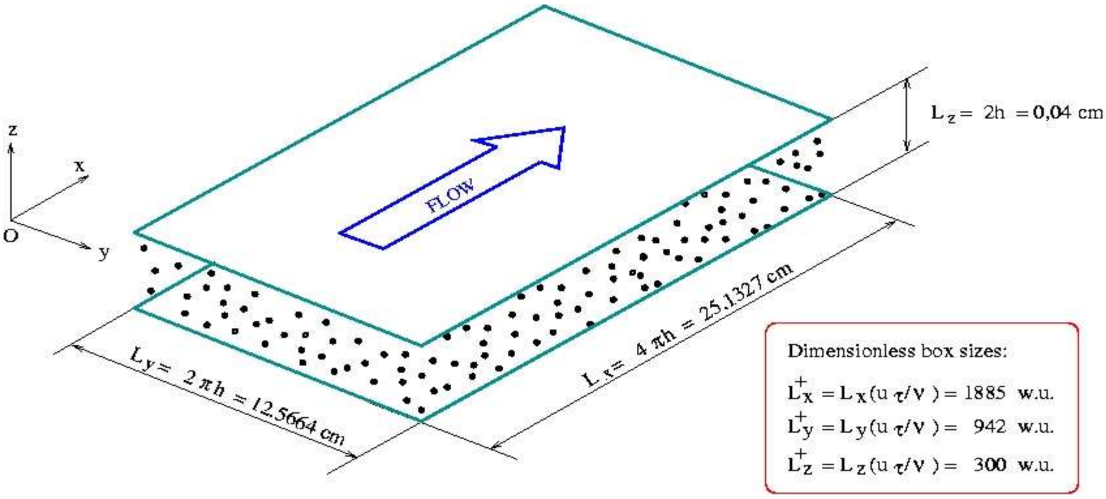
3.1 Fluid:

Shear Reynolds number (Re_τ)[1]	Shear velocity (u_τ)	Density (ρ)	Kinematic viscosity (ν)
150	0.11775 m/s	1.3 kg/m^3	1.57 10^{-5} m^2/s

[1]Shear Reynolds number: $Re_\tau = u_\tau h/\nu$ with h =half channel height (see sketch below).

Note: all variables are made dimensionless (in wall units, identified by the superscript +) using u_τ and ν.

- Physical flow domain:



- Computational domain:

  (i) Grid: N_x x N_y x N_z = 128 x 128 x 129 nodes (at least);

  (ii) Boundary Conditions: periodicity in x and y, no slip at the walls.

3.2 Particles:

Dimensionless Stokes number (St)[1]	Number of tracked particles (Np)	Average volume fraction (Φ_V)	Average mass fraction (Φ_M)
1	> 100000	> 3.52 10^{-8}	> 2.35 10^{-4}
5	> 100000	> 3.93 10^{-6}	> 3.02 10^{-3}
25	> 100000	> 4.40 10^{-5}	> 3.38 10^{-2}

[1] Stokes number: $St = \tau_p / \tau_f$ with $\tau_f = u^2_\tau / \nu$.

- Particles are assumed to be pointwise, rigid and spherical.

- Density: ρ_P= 1000 kg/m^3 (-> ρ_P/ρ = 769.23).

3.3 References:

3.3.1Two-way coupling:

Pan, Y. & Banerjee, S. (1996) *Phys. Fluids*, **8**, 2733-2755.
Boivin, M., Simonin, O. & Squires, K.D. (1998) *J. Fluid Mech.*, **375**, 235-263.

3.3.2 Lift force modelling:

McLaughlin, J. B. (1991) *J. Fluid Mech.*, **224**, 261-274.
Kurose, R. & Komori, S. (1999) *J. Fluid Mech.*, **384**, 183-206.

3.3.3 Inter-particle collisions:

Chen, M., Kontomaris, K., McLaughlin, J.B., (1998) *Int. J. Multiphase Flow*, **24**, 1079-1138.
Sommerfeld, M. (2001) *Int. J. Multiphase Flow*, **27(10)**, 1829-1858.
Sommerfeld, M. (2003) *Int. J. Multiphase Flow*, **29(4)**, 675-699.

For further information, please visit http://www-mvt.iw.uni-halle.de/workshop05/testcases.html or contact: Dr. Cristian Marchioli (e-mail: marchioli@uniud.it)