Test case

Particle-laden jet

(Prof. J. Sinclair Curtis, University of Florida)

Description of the test case

In this test case a particle-laden gas jet issuing into a test chamber with quadratic cross-section (470 mm x 470 mm) is considered (Fig. 1). The height of the test chamber is not known, but for the computations one may assume a height of 1000 mm. The distinctiveness of this test case is the considered rather high particle mass loading at the exit of the injection pipe and the use of different particle sizes including also a binary mixture. Therefore, it is expected that inter-particle collisions play a major role in the dispersion of the jet.

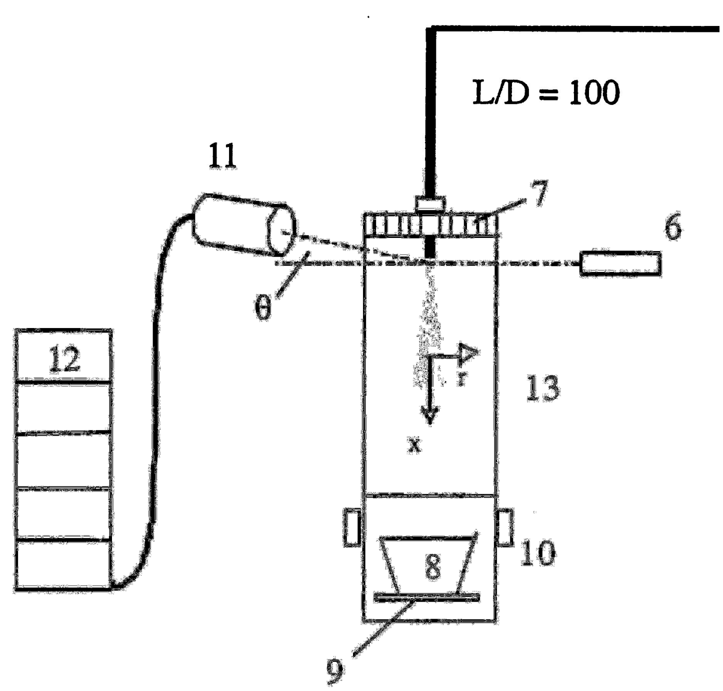

Fig.1 Schematic diagram of the jet flow test section

A sketch of the test section is shown in Fig. 1. The particles are injected through a smooth copper pipe with an inner diameter of 14.2 mm and an outer diameter of 15.9 mm. The straight part of the injection pipe has a length of 1270 mm, corresponding to about 90 L/d. A honeycomb flow straightener is mounted at the top of the test chamber for allowing free air entrainment from the surrounding. Near the bottom of the test chamber fans are connected to evacuate the chamber. This yields a maximum velocity of 0.06 m/s from the surrounding into the test chamber (i.e. through the honeycomb). The particles are collected at the bottom of the test chamber in a container which sits on a load cell in order to estimate the particle mass loading.

Measurements were performed by a two-component LDA/PDA in order to obtain gas and particle velocities as well as the size of the glass beads. The measurement equipment was mounted on a traversing system in order to scan the jet as desired. The two-phase measurements were done in two stages in order to obtain once the gas velocity field in the two-phase flow and then the particle phase properties. At each stage adapted settings of the LDA/PDA were applied in order to ensure proper phase discrimination (see Hadinoto et al. 2005). For allowing gas velocity measurement small spherical tracer particles with a diameter of smaller than 5 µm were added. At each measurement point 1000 coincident samples were collected to obtain statistically reliable averages.

In all the experiments air at atmospheric pressure and at room temperature is used. With the average exit velocity of about 9.64 m/s for the single phase flow, a pipe Reynolds number of 8,400 follows.

The particles used in the experiments where spherical glass beads (density 2,500 kg/m^3) with different mean diameter of 25 and 70 µm and a binary mixture of both particle sizes. The particle sizes provided are based on measurements by a Coulter counter, whereby the averaging is based on particle volume (i.e. not on number as required for most Lagrangian calculations). The size range of the 25 µm-particles is between about 5 – 40 µm and the 70 µm-particles are distributed between 50 – 87 µm (see Fig. 2). The particle mass loading for the mono-sized particle is 1.0 and for the binary mixture the mass loading of each fraction is 0.5.

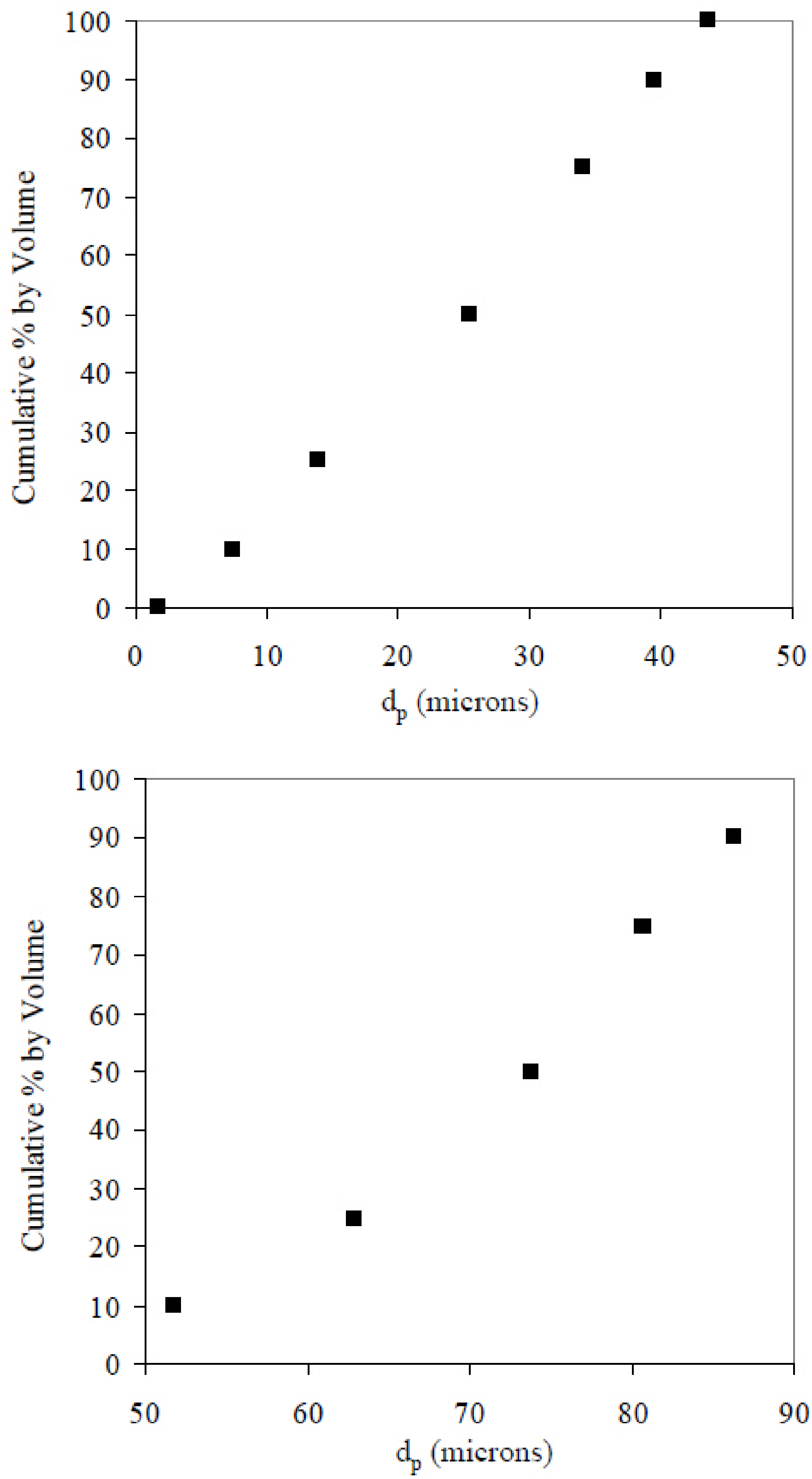

Fig.1 Cumulative size distribution of 25 mm-particles (top) and 70 mm-particles (bottom) obtained by a Coulter counter (particle volume based measurement)

The EXCEL-file contains data for the single phase flow, including inlet conditions and downstream profiles, and the inlet conditions for the three two-phase flow test cases:

Single-phase flow results for validation:	B.1	velocities at nozzle exit
	B.9	centre line velocity measurements
	B.13	profiles for the single phase flow at different axial positions (x/d = 1, 3, 5, 10 and15)
1) Two-phase flow with 25 µm particles:	B.2	gas-phase velocities at the nozzle exit
	B.6	particle velocities at the nozzle exit
2) Two-phase flow with 70 µm particles:	B.3	gas-phase velocities at the nozzle exit
	B.5	particle velocities at the nozzle exit
3) Two-phase flow with binary mixture:	B.4	gas-phase velocities at the nozzle exit
	B.8	velocities of the 25 µm particles at the nozzle exit
	B.7	velocities of the 70 µm particles at the nozzle exit

Due to the strong effect of the two-phase flow behaviour in the narrow inlet pipe the computations could be also done for the inlet pipe. Doing so, the calculated pipe outlet results should be matched with the inlet data provides in the EXCEL sheets.

Data to be provided

For comparison of the computations with the measurements for the three two-phase flow test cases the following data should be provided in separate EXCEL sheets:

Centre line velocities of the gas phase for case 1 and 2 up to x/d = 16.07

x/d	U_g [m/s]	u'_g [m/s]	v'_g [m/s]

Centre line velocities of the particle phase for case 1 and 2 up to x/d = 16.07

x/d	U_p [m/s]	u'_p [m/s]	v'_p [m/s]

Profiles of particle velocities for case 1 and 2 at axial positions of x/d = 5, 10 and 15 in a radial range between -1.5 < r/d < 1.5

r/d	U_p [m/s]	u'_p [m/s]	V_p [m/s]	v'_p [m/s]	$u'_p v'_p$ [m²/s²]

Centre line velocities of the gas phase in the binary mixture (case 3) up to x/d = 16.07

x/d	U_g [m/s]	u'_g [m/s]	v'_g [m/s]

Centre line velocities of the particle phase for case 3 up to x/d = 16.07 (separate velocity profiles should be provided for the 25 µm and 70 µm particles)

x/d	$U_{p,25}$ [m/s]	$u'_{p,25}$ [m/s]	$v'_{p,25}$ [m/s]

x/d	$U_{p,70}$ [m/s]	$u'_{p,70}$ [m/s]	$v'_{p,70}$ [m/s]

Profiles of particle velocities for case 3 at axial positions of x/d = 5, 10 and 15 in a radial range between -1.5 < r/d < 1.5 (separate velocity profiles should be provided for the 25 µm and 70 µm particles)

r/d	$U_{p,25}$ [m/s]	$u'_{p,25}$ [m/s]	$V_{p,25}$ [m/s]	$v'_{p,25}$ [m/s]	$(u'_p v'_p)_{25}$ [m²/s²]

r/d	$U_{p,70}$ [m/s]	$u'_{p,70}$ [m/s]	$V_{p,70}$ [m/s]	$v'_{p,70}$ [m/s]	$(u'_p v'_p)_{70}$ [m²/s²]

References

Hadinoto, K., Jones, E.N., Yurteri, C. and Curtis, J.S.: Reynolds number dependence of gas-phase turbulence in gas-particle flows. Int. J. Multiphase Flow, Vol. 31, 416 – 434 (2005)