Pneumatic conveying of fine particles through a horizontal glass pipe

M. Sommerfeld

Zentrum für Ingenieurwissenschaften, Martin-Luther-Universität Halle-Wittenberg,

D-06099 Halle (Saale), Germany

Introduction

Pneumatic conveying is used in numerous industrial areas for transporting powder within a production process over large distances. One operational condition is dilute phase conveying where particles are more or less homogeneously distributed over the pipe cross-section. However, due to inertial effects particle phase segregation might occur due to gravity or centrifuging in pipe bends. Thereby concentrated regions of particles may develop resulting in higher probabilities of inter-particle collisions. The fluid dynamic transport of the particles is first of all governed by the drag force. In wall bounded flows additionally the slip-shear lift force will become important as a consequence of the strong shear gradients near wall regions. Since the particles will also frequently collide with the pipe wall, they acquire relatively high rotational velocities. This makes also the slip-rotation lift force to become important. Finally, the particle interaction with turbulence will be significant for the considered fine particles. As a result, even the simple case of dilute phase conveying through a horizontal pipe is already quite demanding for numerical predictions (see for example Lain & Sommerfeld 2010).

Test case summary

In the test case a 5.5 m long horizontal glass pipe is considered (Huber & Sommerfeld 1994) having a diameter of 80 mm. The superficial gas velocity is fixed with 23 m/s for all cases considered. Measurements were conducted with air at ambient conditions, i.e. p = 10^5 Pa, T = 298 K. This yields a density of $r = 1.17\, kg/m^3$ and a dynamic viscosity of $m = 18.4 \cdot 10^{-6}\; kg/(m \cdot s)$. The gas phase inlet velocity may be approximated by a plug flow and the fluctuating velocities of all components could be assumed to be around 5 % of the mean velocity. The exact value is not as important since the developed flow at 4.5 m downstream of the inlet will be considered for comparison with the measurements.

The particles considered are spherical glass beads with a size distribution ranging between about 15 to 80 µm and a number mean diameter of about 43 µm. The size distribution is shown in Fig. 1 and tabulated in Table 1. The particles material density is 2,500 kg/m^3. The particle mass loading considered is h = 0.3 and h = 0.7. At the inlet the particles may be injected with the same velocity conditions as the fluid. Regarding the angular velocity of the particles one may assume a mean of zero and a standard deviation of 1,000 1/s.

Size [mm]	PDF [%]
1.54525	0.371025
4.85651	0.318021
8.16777	0.318021
11.479	0.583039
14.7903	1.16608
18.3223	1.74912
21.6336	2.80919
24.9448	4.18728
28.2561	5.77739
31.5673	7.20848
34.8786	8.48057
38.1898	9.16961
41.7219	9.54064
45.0331	8.58657
48.1236	7.36749
51.6556	6.41343
54.9669	5.67138
58.2781	4.34629
61.5894	3.71025
64.9007	2.91519
68.2119	2.33216
71.5232	1.74912
74.8344	1.16608
78.3664	1.06007
81.6777	0.583039
84.989	0.530035
88.3002	0.318021
91.6115	0.265018
94.9227	0.265018
98.234	0.212014

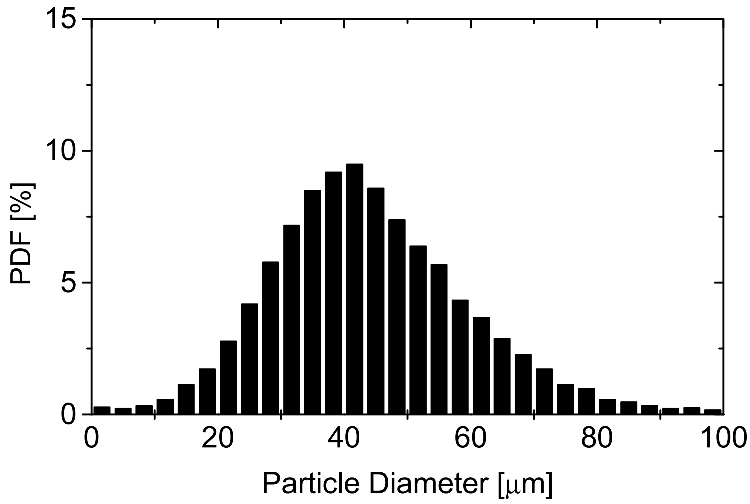

Figure 1: Particle size distribution according to the measurements

Table 1: Data of particle size distribution according to Fig. 1 (size in the centre of each class having a width of 3.33 μm)

Data to be provided

For the cross-sections 2.5 m and 4.5 m downstream of the inlet both fluid- and particle-phase properties shall be provided for vertical profiles through the pipe centre. Please note that experimental data are only available for the particle phase. All the data should be provided on EXCEL sheets in the following order:

gas phase

- vertical coordinate [m]
- stream-wise mean velocity [m/s]
- stream-wise velocity fluctuation [m/s]
- vertical component of velocity fluctuation [m/s]
- turbulent kinetic energy [m^2/s^2]

particle phase (averaged over all size classes)

- vertical coordinate [m]
- stream-wise mean velocity [m/s]
- stream-wise velocity fluctuation [m/s]
- vertical velocity fluctuation [m/s]
- lateral velocity fluctuation [m/s]
- fluctuating energy of particle phase [m^2/s^2]
- particle concentration [kg/m^2]
- number mean particle diameter [µm]

Moreover the pressure drop along the entire pipe shall be provided in comparison with the single-phase flow result. For further characterising the particle behaviour the particle wall collision frequency [1/m] and the inter-particle collision rate [$1/m^3s$] should be provided for the pipe section between 4 and 5 m.

References

Huber, N. and Sommerfeld, M.: Characterization of the cross-sectional particle concentration distribution in pneumatic conveying systems. Powder Technology, 79 (1994) 191-210

Lain, S. and Sommerfeld, M.: Euler/Lagrange computations of particle-laden gas flow in pneumatic conveying systems. 7th International Conference on Multiphase Flow, ICMF 2010, Tampa, FL, USA, May 30 – June 4, 2010