Measurement of flows in randomly packed beds using the Particle Image Velocimetry

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Randomly packed beds are frequently used in the chemical and process industry as reaction, separation or purification units. The design of these reactors is usually based on simplified models such as the plug flow assumption which fails for large ratios of particle to tube diameter (d/D > 0.1) due to non-uniformities of the porosity distributions and the velocity field. To model such flows, empirically parameters are needed and have to be obtained experimentally after evaluating velocity fields in the bed. Due to the complexity of the geometry, classical methods such as pitot probes or hot wire anemometry are not appropriate and therefore non-intrusive measurements may provide more detailed results. As example, the magnetic resonance imaging (MRI) technique provides three dimensional results, but is limited to non-metallic and non-magnetic materials and requires a substantial investment in equipment, while the laser Doppler anemometry (LDA) method may be used in transparent test sections after carefully matching the refractions indexes of the fluid and of the embedded elements and confining tube, but as an interferometric technique, it is very sensitive to variations of the refractive indexes and provides only point data. In this paper, the particle image velocimetry (PIV) is used since it allows determining the velocity field along a plane and is less sensitive to differences of the refractive indexes. The intention of this work is to provide reference data that allows a direct comparison with result of numerical simulations.

The setup consists of the test section, a RPM regulated pump, venture nozzle, temperature control and expansion tank as shown in figure 1. The test section itself contains randomly placed glass spheres confined by a cylindrical tube of the same material, with 50 mm inner diameter. Two different spheres (9 and 30 mm) are used. A carefull matching of the refraction indexes of oil and glass has obtained. For the chosen regime of Reynolds number Re_D = 10-50,(depending on the diameter of the spheres), the flow is in steady state. In a first step of the experiments, measurements are obtained for the midplane of the packed bed, parallel to flow direction. Due to the lower porosity of this configuration, significantly higher velocities are observed in the tube filled with 9 mm spheres as in the tube filled with 30 mm spheres. In the second step, the axial velocity in the entire fixed bed is reconstructed from two dimensional measurements taken along various meridian planes. The latter are obtained by rotating the inner cylinder containing the embedded spheres. This representation allows to observe the channeling effect, as shown in figure 2, for the tube filled with 9mm spheres.

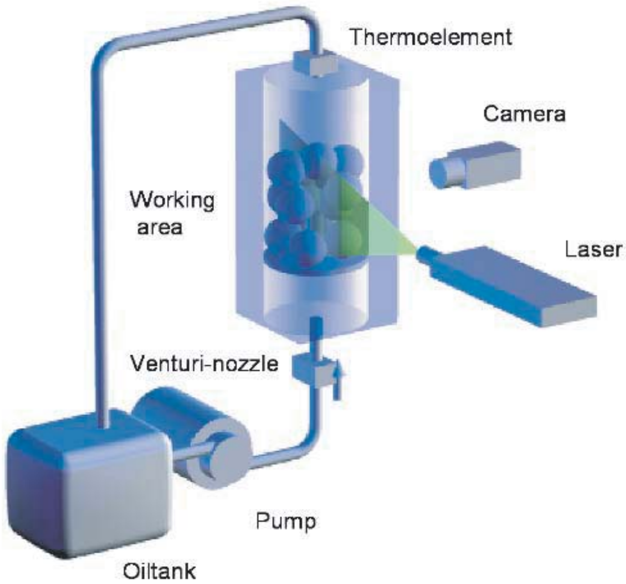

Fig. 1 Experimental setup

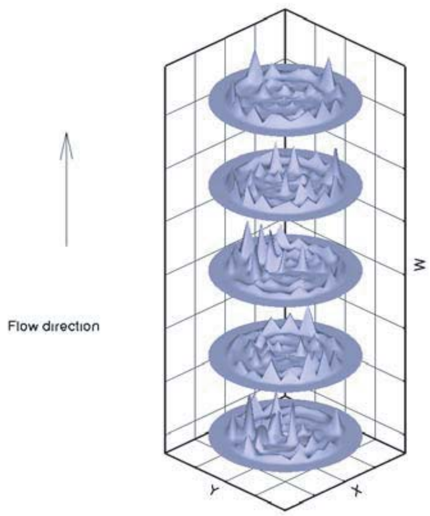

Fig. 2 Axial velocity along the tube (9 mm spheres)

The present paper demonstrates that the PIV method may be used to examine the flow in packed beds and geometries with similar complexity. Thus, PIV is an alternative to more expensive and laborious measuring techniques such as MRI or LDA. For the reconstruction of the whole velocity field, measurements with two cameras (stereo-PIV) are planned.