Development of an Experimental Flow Configuration for the Study of the Effects of Mixing on the Nucleation and Growth of Liquid Droplets

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The nucleation and growth of liquid droplets is greatly sensitive to many hydrodynamic quantities such as residence time, strain, vapour concentration, and temperature.

This work describes the development of a laboratory scale stagnation flow for the measurement of the nucleation and growth of di-butyl-phthalate (DBP) liquid droplets in laminar conditions as a function of various hydrodynamic parameters. The set up consists of two opposed jets, such that a stagnation plane forms between the two nozzles. The upper stream consist of hot nitrogen saturated with DBP vapour; the lower stream of dry cold nitrogen. DBP nucleates at the stagnation plane where the hot stream mixes with the cold stream. Provided the Reynolds number of the flow is high enough, the counterflow configuration is characterized by a single parameter, the strain rate or equivalently the resident time. The residence time and strain rate, defined as $a = 2V/L$, are changed by varying the flow rate V of the streams and the separation between the two nozzles L.

The focus of this study is the analysis of the velocity field and the definition of a suitable operation map for the various parameters, such as flow rates, nozzle separation, and diameter. For sake of simplicity the present experiment both the upper stream and the lower stream consist of pure dry nitrogen. Particle image velocimetry is used to measure the velocity field. The analytical solution for the counterflow is available (Chapman and Bauer, 1975; Seshadri and Williams 1978). The computed dimensionless axial velocity and its gradient $\theta' = L/V \cdot dv_z/dz$, where v_z is the axial velocity on the centerline and z is the axial coordinate. Are compared with the corresponding experimental data (Fig. 1). It can be observed that the measured velocity shows a remarkable agreement with the analytical solution.

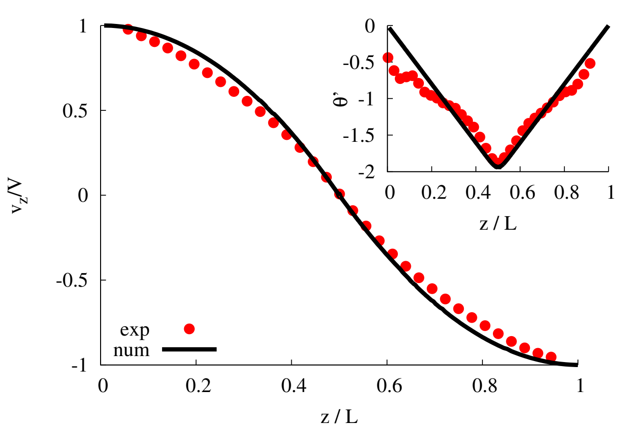

Figure 1: Nondimensional axial velocity and gradient (inset) along the centerline.

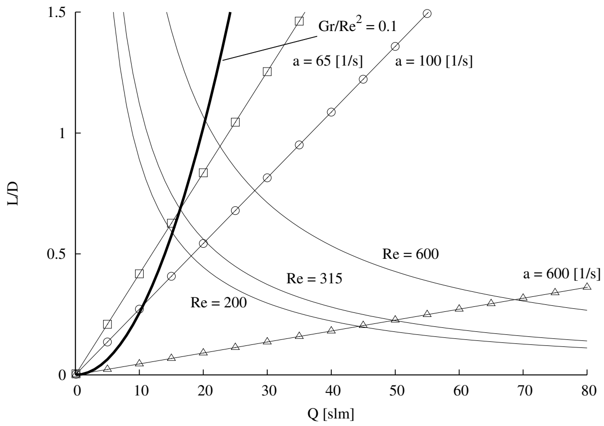

Figure 2: Operation map for the counterflow with nozzle diameter 25 mm. The Reynolds number is defined using half of the separation, the exit velocity, and the nitrogen kinematic viscosity: $Re = V(L/2)/\mu$.

Figure 2 shows the operation map of the set up. The lower limit for L/D is 0.3, due to geometrical constraints for optical access. Below $Re = 200$ the sensitivity to external perturbation is too high to obtain reliable measurement. For $Re > 600$ turbulence instabilities start to develop. In order to avoid buoyancy effects related to the density difference between hot (425 K) and cold (273 K) nitrogen streams, the parameter set is restricted to the region on the right of the line $Gr/Re^2 = 0.1$, where Gr is the Grashof number.

In conclusion, the velocity field has been characterized and the ranges of operative conditions have been assessed. The setup can be used to study the coupling between the aerosol and the hydrodynamics parameters.

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