Experimental and numerical investigation of evaporating mono-component droplets in a turbulent channel flow

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Abstract

This paper deals with the experimental investigation and numerical simulation of a cloud of monocomponent droplets in a highly turbulent flow. Experimental data and numerical results are compared in order to validate the evaporation models implemented in the computing code.

Introduction.

The main goal of this work is to study the behavior of evaporating droplets in a highly turbulent channel flow. The liquid dispersed phase is studied in terms of droplet size, velocity and temperature evolutions in the channel.

For this purpose, an experimental setup was mounted using the following measurement methods: the Global Rainbow Thermometry (GRT) and Phase Doppler Anemometry (PDA).

The ONERA's computational code CEDRE is used to calculate the motion, the heat and the mass exchange between the heated air and the liquid, dispersed phase.

Materials and Methods

The experimental setup consists in a vertical square cross-section channel with optical access (Figure 1). Preheated air is injected in a tank and passes through a turbulence generator before entering the channel. The generator is made of a circular plate perforated by 45 holes of 3mm diameter and a convergent. The 45 jets impinge the convergent generating a high turbulence level.

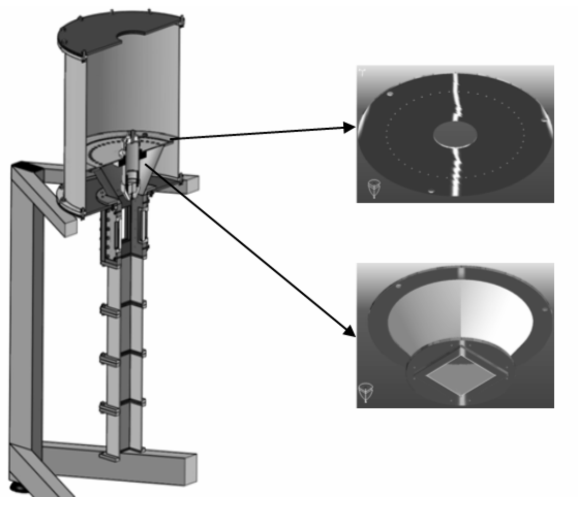

Figure 1. Experimental setup

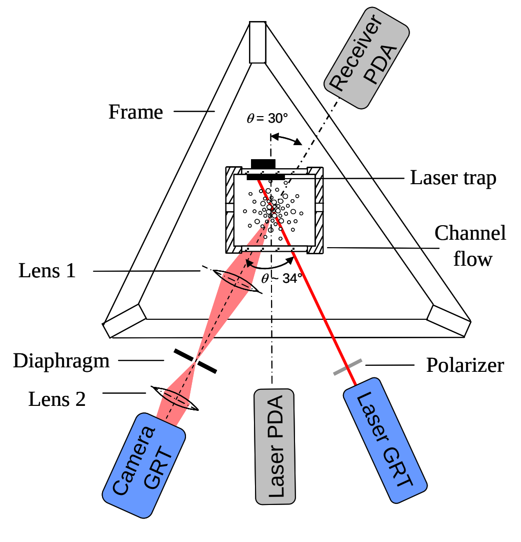

Figure 2. Schematic top view

An ultrasound atomizer is placed in the centre of the perforated plate and the atomisation surface is located at the entrance of the channel. The atomization process provides droplets with a wide range of diameters and velocities. These droplets are quickly dispersed in the carrier flow. The positioning of the GRT and PDA equipments with respect to the channel flow is described in Figure 2.

In the second part of the paper the results of a Large Eddy Simulation (LES) of this multiphase flow are presented. The simulation is performed with the ONERA CEDRE code.

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The grid is constructed such that it can resolve the large eddies. The smaller one, that are supposed to be isotropic are modelled by a subgrid scale model. For this simulation, a standard Smagorinsky model is used.

A two-way coupling treatment of the spray dynamics is realised through an Eulerian-Lagrangian approach. The discrete phase is solved by a Lagrangian tracking methodology. The main advantage of this technique is that it allows a detailed study of the droplets.

The unsteady technique used in the numerical computation consists in the following of a large number of numerical droplets representing real droplets with close properties: position, radius, velocity, temperature. Various effects as droplet collision, break-up and coalescence are neglected in reason of small liquid volume fractions.

Results and Discussion

The air flow is experimentally characterized in terms of velocity fields using LDA with small oil droplets as tracers [3,5].

For the liquid phase, the droplets diameter, velocity and temperature are measured at different distances from the atomiser. The diameter and velocity probability functions are recorded in order to have information about the droplets turbulent dispersion and evaporation rate inside the channel flow. The droplets mean temperature is also measured to evaluate about the heat transfer between the two phases.

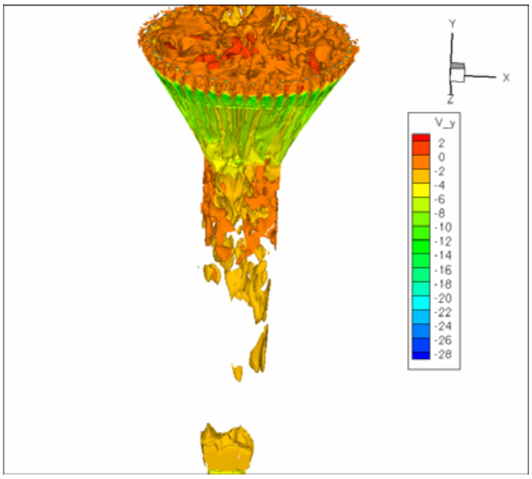

Figure 3. Tree dimensional velocity contours

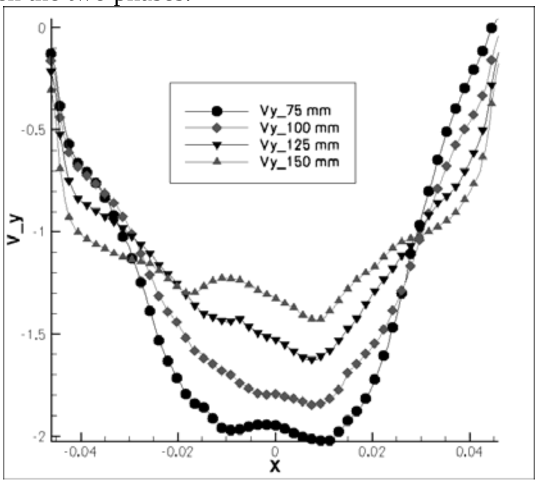

Figure 4. Longitudinal velocity profiles.

Simulations are firstly performed only for the continuous phase without droplets (Figure 3). Even though there are still some discrepancies between experimental and numerical values, the evolution of the mean longitudinal velocity downstream the channel (Figure 4) shows good agreement with the experience [5].

In a second step, the liquid phase is injected and the influence of the turbulent flow on droplet dispersion and evaporation is observed and compared with experimental results.

Acknowledgement

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Nomenclature

GRT Global Rainbow Thermography
PDA Phase Doppler Anemometry
LES Large Eddy Simulation

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