

On the use of LDV measurements for *in-vitro* aerosol deposition studiesPedro J. Mendes¹, João F. Pinto², João M. M. Sousa¹1: Mechanical Engineering Dept., Instituto Superior Técnico, Portugal, pjmendes@navier.ist.utl.pt, msousa@alfa.ist.utl.pt2: Pharmaceutical Technology Dept., Faculdade de Farmácia de Lisboa, Portugal, jfpinto@ff.ul.pt**Keywords:** Dry powder inhaler, laser-Doppler velocimetry, pharmaceutical aerosol, Twin Impinger

1. Aim

LDV characterization of the turbulent flow inside a Twin Impinger (TI) for *in-vitro* deposition studies using stochastic Lagrangian particle tracking.

2. Methodology

The standard TI is constructed in DURAN® glass (refractive index, $n=1.473$) and presents highly curved surfaces. Such characteristics lead to the requirement of applying a procedure for refractive index matching in the course of the LDV measurements, which precludes the possibility of using air as the working fluid. Usable fluids exhibiting the required value of n usually present a high viscosity, thus demanding large pumping power and leading to significant heat generation. For this reason, in a preliminary phase, water has been employed to minimize lens effects. Subsequently, exact refractive index matching has been achieved by the use of a special fluid (weißöl FC 2012 W, Fauth & Co) in a thermostatic bath, but this introduced limitations on the range of investigated flow rates. Consequently, a critical assessment of errors had to be made in order to understand the implications of imperfect refractive index matching on the subsequent modeling procedure, namely in the vicinity of the walls. Dynamical similarity with air was prescribed throughout the experiments. Unfortunately this constraint cannot be met simultaneously for the particulate phase and therefore only information pertaining to the mean and turbulent flow fields of the continuous phase was gathered by laser-optic techniques.

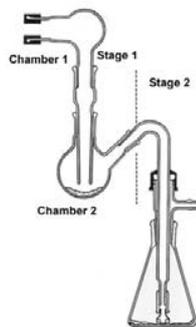


Fig. 1 Schematic representation of the Twin Impinger

Prior to the LDV measurements, visualization tests of the flow inside the TI were performed to identify critical regions and provide a preliminary view of the flow physics. To obtain tracers, particles of Iridium 100 Silber perl (Merck, Germany) were suspended in water. Both still and motion digital pictures of the flow patterns were taken using a laser light sheet to illuminate various sections of the TI.

The LDV measurements were carried out employing a two-component fiberoptic system (DANTEC, DK) operating in backward-scatter mode. Mean and turbulent velocity fields were measured in several sections of the TI. Two values of constant flow rate of water were considered: 1.98 liters/min and 3.54 liters/min, at a temperature of $25\pm 1^\circ\text{C}$. The corresponding values of the Reynolds number, based on the inlet velocity and diameter of the first stage of the TI, were 1.6×10^3 and 2.8×10^3 , respectively. Nylon particles $5\pm 1.5\mu\text{m}$ in diameter (DANTEC, DK) were used for seeding.

A numerical model for the two-phase flow inside the first chamber of the TI has been developed using Lagrangian particle tracking of the dispersed phase. An Eulerian model for the continuous phase was constructed using the detailed LDV data. A stochastic eddy-interaction model has been used to simulate the effects of turbulence. The particles moved inside the TI due to inertia, drag, gravity and virtual mass forces. Their interaction with the walls of the device considered a coefficient of restitution, which depends on the impact angle. Adhesion of particles to the walls was assumed when their kinetic energy after impact was not sufficient to compensate van der Waals forces. Particle-particle interaction was neglected.

3. Results

It was demonstrated that the LDV measurements were able to capture the details of the top recirculation zone and the pair of large Dean vortices. Appropriate resolution of the near-wall region seems to have been obtained as well. The vortices are responsible for the strong secondary flow occurring inside the first chamber and along the pipe communicating with the second chamber of the TI. Spectral analysis of velocity time series indicated a quasi-periodic, low-frequency component in the flow. The comparison of the non-dimensional mean and turbulent flow fields for the two investigated flow rates (asthmatic and normal) has shown identical results.

The deposition study considered 15,000 particles of lactose with a diameter of $5\pm 1\mu\text{m}$ and a Gaussian distribution. The results indicated that approximately 38% of those were retained in the first chamber of the “virtual” TI. Such value is consistent with the data produced by assaying the particles of a model drug released from a commercially available inhaler.

4. Conclusions

The flow inside the TI displays high complexity, thus major difficulties in turbulence modeling may be anticipated.

The study has demonstrated that the coupled use of LDV and stochastic Lagrangian tracking can be used to reproduce particle deposition inside a TI, thus these results may be correlated also with particle deposition in the human tract.