

## Paper 23.1

### Phase Doppler anemometer for instantaneous measurements of droplet concentration

by

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#### ABSTRACT

In two-phase flows, droplet concentration fluctuations can occur due to the atomisation process of a liquid or the interaction of droplets or particles with turbulent structures. The importance of the amplitude of droplet concentration fluctuations caused by nearly deterministic processes in sprays has not been quantified partly due to difficulties associated with measurement techniques. The current work describes an approach to obtain measurements of droplet concentration fluctuations and applies it in a swirl-stabilised burner to quantify droplet concentration fluctuations.

A method was developed to quantify deterministic droplet concentration fluctuations based on Phase Doppler Anemometry (PDA). The method sampled time-dependent droplet velocity and size measurements within equal sampling times to determine instantaneous droplet concentration. Two methods were used to define instantaneous droplet concentration : *the first* was associated with the data rate of droplets within the sampling time and *the second* was defined by the sum of residence times of all droplets crossing the probe volume of the anemometer divided by the sampling time and the volume of the probe volume of the anemometer for different droplet sizes. Analysis of the instantaneous data was developed to calculate the mean and rms values of instantaneous droplet concentration. The resulting droplet concentration fluctuations were due to random appearance of single droplets and deterministic appearance of droplet clouds in the probe volume and their values could be quantified from the energy of the deterministic fluctuations in the frequency spectra within the frequency bandwidth of the associated process.

The data processing method of PDA measurements was assessed in a pulsated injector operating at frequency of 20 Hz, injecting a liquid spray in the swirling flow of a laboratory burner. Comparisons between droplet concentration fluctuations, measured by a light scattering technique and phase Doppler measurements indicated agreement within 15%. The technique was applied in the swirl burner to measure the amplitude of deterministic droplet concentration fluctuations of an otherwise steady spray, which were caused by the unsteadiness of the atomisation process, which occurred at frequencies between 400 and 800 Hz. The intensity of droplet concentration fluctuations due to the break-up process was quantified to 15% of the mean droplet concentration in the flow.

The frequency spectra of droplet velocities and concentrations within two droplet size ranges, 1-20 and 20-60  $\mu\text{m}$ , were measured. Velocity fluctuations of droplets smaller than 20  $\mu\text{m}$  indicated the gas flow velocity fluctuations and showed the presence of a deterministic unsteadiness in the flow field at the same frequency as the break-up unsteadiness. This was well correlated with regions of the flow where droplet concentration fluctuations were maximum and, therefore, the deterministic droplet concentration fluctuations with amplitude 15% of the mean value could modify the gas flow velocity. Droplets larger than 20  $\mu\text{m}$  were mostly influenced by the unsteadiness of the atomisation process and had droplet concentration and velocity fluctuations in the frequency bandwidth of 400 to 800 Hz, associated with the break-up process.