

Planar and point-wise measuring techniques for in-situ particle characterisation

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Abstract

Particles are involved in an enormous number of industrial and technological processes. Especially droplets play an essential part in daily life. Measurement techniques for the characterization of particles are essential for controlling of processes, optimization of products, description of material properties or validation of numerical tools for two-phase flow simulations. A number of planar point-wise measurement techniques became available in the last years and the development of techniques for inhomogeneous and non-spherical particles is initiated by a several works. The paper deals with short description of in-situ optical counter techniques for single particle characterization and discusses the basic limitations of these techniques in terms of fundamental light scattering properties. Only with such so-called counter techniques fluxes and flux densities of, e.g. volume, mass, etc, can be estimated.

Most of the measuring techniques are limited to the simplest shape of a homogeneous spherical particle. Problems for measurement of non-spherical particles arise because the specification of the orientation plays a role in addition to the shape parameters.

When a particle is illuminated by one laser beam and the scattered light is detected by one receiver (see Fig.) only a few light paths through the particle, corresponding to the incident and glare points of the scattering orders, are relevant for the signal. The detected scattered light carries only information about particle properties near these interaction points. All other particle regions are not illuminated for this special receiver location.

Most systems assuming, that the glare point distance scales linearly with the particle diameter. This is only valid for the spherical shape with arbitrary orientations or for complex particles with a defined orientation. Under these assumptions the glare point distance can be measured directly and leads to the glare point imaging technique. The distance between the glare points can also be measured indirectly by interference fringe spacing in case of coherent illumination. The following techniques use interference from two glare points: phase Doppler technique, interferometric particle imaging, ILIDS, rainbow

refractometry. The glare points could arise from two incident laser beams (phase Doppler) or two scattering orders (interferometric particle imaging, rainbow).

This inverse problem of parameter estimation becomes very difficult for other particle structures, especially when different orientations of the particle can be expected. For non-spherical particles the glare points can be interpreted in a number of different ways, resulting in different possible particle shape reconstructions.

Additional glare points can be generated from higher order refraction or additional illuminating beams. Both possibilities are used for non-sphericity detection in phase Doppler and interferometric particle imaging system or in the rainbow and dual burst technique for estimating the refractive index.

The inverse problem can be also solved for spherical homogeneous particles by a measurement of the distance between the incident points. In case of a shaped beam and a moving particle the signals from the different incident points are separated in time. This time difference can be related to the particle size, again under the assumption that the incident point distance scales linearly with particle size. This inverting strategy is used in the time-shift technique, which can also be applied in backscatter.

One exception of the limited information from glare points is the shadow or the diffraction in forward scatter from single particles. Therefore the shadow and diffraction is also used in a number of techniques, e.g. direct imaging, the shadow Doppler technique or inline holography.

For reliable flux and concentration measurements the detection volume dependences on particle size and optical configuration should be known. Except for the phase Doppler technique these dependences are not yet investigated for the recent developed techniques. Especially for shadow imaging the accuracy of sizing depends on the detection of the sharp particle border. Blooming and defocusing effects limit the accurate determination of the particle location along the optical axis. Therefore the detection volume is not well defined and reliable flux and concentration measurements are extremely difficult with backlighting imaging techniques.