Development and application of the Multi Wavelength Light Extinction technique for the characterization of nano- and microparticles

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Abstract

Because of the large industrial and scientific interest in nanoparticles and nanoparticle flows, the requirement towards an online, submicron particle characterization technique is strongly expressed.

In the frame of the present PhD research a non-intrusive, optical measurement technique, the Multi Wavelength Light Extinction (MWLE) technique will be developed. It has several significant advantages compared to other existing measurement techniques. The MWLE technique is capable to measure the size distribution and concentration of the particles simultaneously, from several micrometres down to 30nm. The technique requires a simple and low-cost experimental apparatus and minimal optical access to the examined particles. These two properties make the technique suitable for online measurements in a large variety of situations. The shape of the investigated particles can be incorporated in the mathematical modeling, thus allowing the possibility for the qualitative evaluation of the particle shape, too.

The MWLE technique relies on relating the light transmittance spectrum of a particle cloud to the characteristics of the constituent particles.

The development was started with a bibliographic research on the field of light scattering by non-spherical particles. After the thorough understanding of the related theories, an appropriate mathematical model will be obtained. Two different cases will be considered; light scattering by airborne particles and particles deposited on a transparent substrate. Using the model, light scattering simulations will be carried out firstly to investigate the effect of the particle non-sphericity; secondly for the generation of the appropriate model parameters for the measurement of solid, metallic particles in both of the mentioned configurations. The retrieval of the particle size characteristics from the experimental data requires the solution of a Fredholm integral equation of the first kind, which is an ill-conditioned problem. Thus, the mathematical background of inverse problems will be studied. After, an inversion algorithm will be developed, which is robust, accurate and fast enough for the analysis of real measurement data.

After obtaining the necessary numerical and theoretical tools, the technique will be validated through the characterization of the size, concentration and fractal dimension of metallic nanoparticles and aggregates carried by a subsonic flow. The reference technique to be used will be the DMA-CPC (Differential Mobility Analyser Condensation Particle Counter) particle spectrometer. The latter investigation will be a preparation for the application of the technique in a nanoparticle production plasma facility. The aim will be to determine the particle characteristics as function of the operating parameters of the plasma facility.

The measurement technique will be further tested in the other mentioned configuration: particles deposited on a transparent substrate through the evaporation of a thin liquid layer will be examined. The prepared samples will be analysed by SEM (Scanning Electron Microscope), in order to provide a proper validation of the size analysis capabilities of the technique.

Keywords: nanoparticle, particle size distribution, light extinction, inverse problem, regularization