2 Concept and fundamental theory

The newly developed principle of CDMA combines the concepts of DMA and AAC. In general, the CDMA consists of two concentric cylinders between which high voltage can be applied, and/or both of which can be rotated at the same angular speed. This means that both the voltage and the speed can be superimposed, whereas in the DMA, only the voltage can be varied, and in the AAC, only the speed. This means that with the CDMA, particles can be classified according to their drag force and mass. In the DMA particles are usually characterized by their mobility diameter d_m (i.e. the diameter of a spherical particle experiencing the same drag force for a given relative velocity as the actual particle) (Friedlander, 2000). The AAC typically uses the aerodynamic diameter d_{ae} to characterize particles (i.e. the diameter of a sphere with unit density and the same settling velocity) which has the advantage that all particles of the same settling velocity in the centrifugal field will have the same equivalent diameter (Tavakoli and Olfert, 2014). However, particles with exactly the same shape but different material density will show different aerodynamic diameters. Since in our instrument the two-dimensional characterization mainly aims

to characterize the particle shape, we suggest to use the Stokes diameter d_{St} instead (i.e. the diameter of a sphere of the same density with the identical settling velocity w_S as the actual particle) for characterization (Colbeck, 2013; Reist, 1993). Although both equivalent sizes are closely related, the Stokes diameter does only depend on particle shape, e.g. characterized by the volume and mobility equivalent diameters d_v and d_m, respectively (Baron et al., 2011):

$$d_{St} = \sqrt{\frac{18\eta}{\rho_S \cdot b \cdot Cu(d_m)}} \cdot w_s = \sqrt{\frac{\rho_0}{\rho_S}} \cdot d_ae = \sqrt{\frac{d_v^3}{d_m}} \quad (1)$$

With η as the dynamic viscosity, ρ_S the solid density of the particle material, ρ_0 unit density of $1000\,\frac{\mathrm{kg}}{\mathrm{m}^3}$, b centrifugal or gravitational acceleration, w_S settling velocity. In particular, the Stokes and mobility diameter become identical in the case of a perfect sphere. However, the calculation of the Stokes diameter from classification according to settling velocity in the CDMA centrifugal field does require the knowledge of the particle density. Therefore, if the density is not known with sufficient accuracy or if an aerosol consisting of different materials is analyzed, the aerodynamic diameter should be used as in classical AAC theory. This can be easily adapted in the inversion algorithm. However, if the density of the particles is unknown, shape information is no longer accessible. By measuring all voltage-speed combinations, a full two-dimensional particle size distribution in terms of d_{st} and d_m can be calculated by data inversion.