On the validity of the projected-area approximation of the equivalent mobility radius of power-law aggregates

A.D. Melas[1], L. Isella[2], A.G. Konstandopoulos[1,3] and Y. Drossinos[4]

[1]Aerosol & Particle Technology Laboratory, CPERI/CERTH, P.O. Box 60361, GR-57001 Thessaloniki, Greece
[2]European Commission, Joint Research Centre, B-1050 Brussels, Belgium
[3]Department of Chemical Engineering, Aristotle University, P.O. Box 1517, GR-54006 Thessaloniki, Greece
[4]European Commission, Joint Research Centre, I-21027 Ispra (VA), Italy
Keywords: mobility radius, projected area, fractal-like aggregates.
Presenting author email: amelas@cperi.certh.gr

The transport properties of a particle depend on the ratio of the gas free mean path (λ) to a particle's characteristic length (L), expressed *via* the Knudsen number, $Kn=\lambda/L$ (Friedlander, 2000). The Knudsen number specifies three different aerosol flow regimes: continuum ($Kn=0$), free molecular ($Kn=\infty$), and transition ($0<Kn\leq10$) regimes.

Spherical particles, $L=R_1$ with R_1 the particle radius, often form aggregates with complex structure described by the power law, $N=k_f(R_g/R_1)^{d_f}$, where N is the number of spherical monomers, k_f the fractal prefactor, d_f the fractal dimension, and R_g the radius of gyration (Forrest and Witten, 1979). Transport and structural properties of an aggregate are frequently expressed in terms of equivalent spheres of appropriately chosen radii that reproduce the desired particle property, e.g., the equivalent mobility radius (R_m) is the radius of a sphere with the same mobility as the non-spherical aggregate under identical flow conditions.

In the continuum (momentum transfer) regime, the particle's friction coefficient, calculated by the creeping flow Stokes equations, is proportional to the mobility radius, while in the free molecular regime, according to the theory of gases, it is proportional to the squared mobility radius $R_m(\infty)$. Moreover, $R_m(\infty)$ is related to the orientationally-averaged projected area. In the transition regime, the mobility radius is usually calculated by correcting the continuum-regime mobility radius by a slip correction factor that depends on the Knudsen number. For the mobility radius, the corresponding mobility Knudsen number is $Kn_m=\lambda/R_m$. Different radii may be also used to define appropriate Knudsen number, like the adjusted-sphere radius R_{adj}, the radius of a sphere that has the same slip factor as the aggregate over the entire transition regime. The adjusted-sphere Knudsen number is $Kn_{adj}=\lambda/R_{adj}=KnR_1/R_{adj}$.

Rogak *et al.* (1993) found experimentally that the mobility radius of aggregates of maximum mobility radius $R_m=200$ nm can be reasonably estimated by the projected area approximation, i.e. by the approximation of the transition-regime mobility radius by the free-molecular mobility radius. This approximation has been used in both experimental and numerical studies (see, for example, the recent work of Liu and Chakrabarty, 2016). However, its range of validity beyond the free molecular regime has not been adequately explored yet.

Previously, we calculated the mobility radius of fractal-like aggregates with the Collision Rate Method: we proposed numerical expressions that relate it to the number of monomers and radius of gyration for Kn in the whole transition regime (Melas *et al.*, 2014). Herein, we estimate the mobility radii of different aggregates using these expressions, and we compare them to their free molecular mobility radius $R_m(\infty)$. Figure 1 presents the ratio $R_m(Kn)/R_m(\infty)$ for DLCA aggregates, ($d_f=1.8$,$k_f=1.3$), as a function of the Knudsen number. The black line shows the free molecular mobility radius, which also provides a lower bound. The ratio depends on N and Kn. For aggregates with a small number of monomers the projected area approximation provides a reasonable estimate of R_m for all Kn. Further calculations will be performed for different structures, the projected area approximation range of validity will be examined, and its range of validity will be related to aggregate characteristic Knudsen numbers.

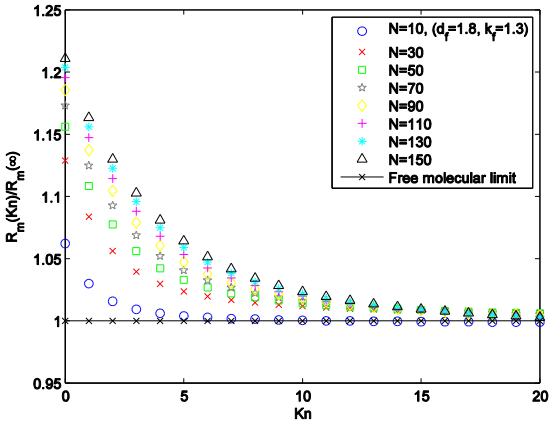

Figure 1. Ratio of the mobility radius to the free molecular mobility radius as a function of the Knudsen number.

Friedlander, S.K. (2000) *Smoke, Dust, and Haze*, Oxford University Press, New York.

Forrest, S.R. and Witten, T.A. (1979) *J. Phys. A* **12**, L109-L117.

Rogak, S.N., Flagan, R.C. and Nguyen H.V. (1993) *Aerosol Sci. Technol.* **18**, 25-47.

Liu, P. and Chakrabarty, R.K. (2016) *Aerosol Sci. Technol.* **50**, 63-70.

Melas, A.D., Isella, L., Konstandopoulos, A.G. and Drossinos Y. (2014) *Aerosol Sci. Technol.* **48**, 1320-1331.