INFLUENCE OF SHAPE FACTOR AND EFFECTIVE DENSITY ON AERODYNAMIC SIZING OF PARTICLES GENERATED BY THE MSP/TSI 1520 FLOW-FOCUSING MONODISPERSE AEROSOL GENERATOR (FMAG)

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Abstract

The Flow-focusing Monodisperse Aerosol Generator (FMAG, Model 1520) from MSP/TSI generates highly monodisperse particles from both solid and liquid solutions. While liquid particles may safely be assumed to be spherical and to have the same density as the bulk substance, those assumptions are not always directly applicable for solid particles. Both shape factor and effective density can influence the actual aerodynamic size of the generated solid particles. This has implications for the user both in preparing solutions for aerosol generation, and for reporting the calculated aerodynamic diameter of these particles.

This work explores the influence of shape factor and effective density on the agreement between experimental and theoretical aerodynamic particle sizes.
Monodisperse supermicron particles of different compositions, including ammonium sulfate, sodium chloride, oleic acid, glycerol, etc., were generated by the FMAG using the same volume fraction solution. Their aerodynamic sizes were measured by an Aerodynamic Particle Sizer (APS, Model 3321). Published literature values for shape factor and effective density were applied to calculate the theoretical aerodynamic size.

Experiment

- Aerosol generation: the Model 1520 FMAG was used with a variety of solutions and suspensions to create particles from the following materials:
  - Solids: ammonium sulfate, sodium chloride, bovine serum albumin, PSL
    Liquids: oleic acid, glycerol
- Particle sizing: the TSI Model 3321 Aerodynamic Particle Sizer (APS) was used to measure the aerodynamic size of the resulting particles.

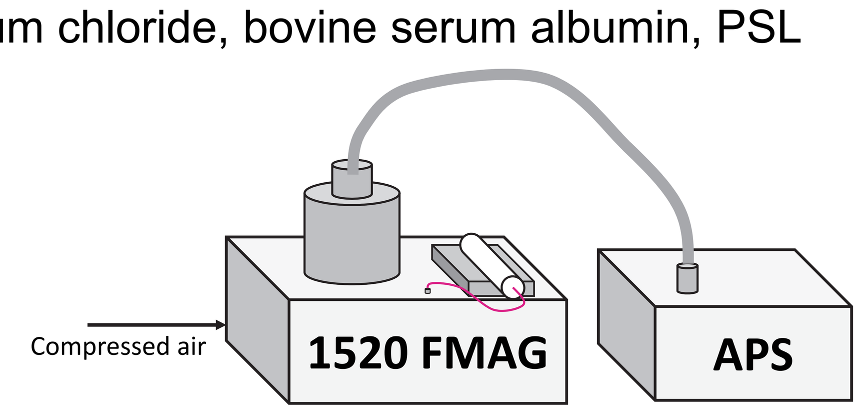

Fig. 1: Experimental schematic.

Data Interpretation

- The volume-equivalent particle diameter is calculated from FMAG operating parameters and the solution concentration.
- Volume-equivalent particle diameter (D_e) relates to aerodynamic diameter (D_a) via particle (material) density:

$$D_a = \sqrt{\rho}(D_e)$$

- Beyond this, aerodynamic diameter is further affected by:
  - Effective density (ρ_{eff}): void spaces reduce the particle's density
  - Shape factor (χ): the physical shape of the particle alters its aerodynamic behavior

  In order to account for both density and shape factor, then, the equation must be modified (most applicable to solid particles):

$$D_a = \sqrt{\rho_{eff}}\left(\frac{D_e}{\sqrt{\chi}}\right)$$

- Literature values for effective density and shape factor were used as context for data interpretation on a material-specific basis (see Table 1).

Table 1: Literature values for density (bulk and effective) and shape factor (assumed and experimental) for particles of various materials.

Particle Property		PSL	Glycerol	Oleic Acid	Ammonium Sulfate	NaCl	BSA
Density	Bulk	1.05	1.26	0.895	1.77	2.16	1.32 (1)
	Effective				≥ 1.67 (2)	≥ 1.75 (2)	≥ 1.0 (3)
Shape Factor	Assumed	1.00	1.0	1.0	1.0	1.08	1.0
	Experimental				≤ 1.07 (2, 4)	1.02 – 1.3 (4)	≤ 1.1 (3)

Results

With one plot per type of particle material, each figure shows:
- *x*-axis: theoretical aerodynamic size of the particles (includes bulk density, assumed shape factor)
- *y*-axis: measured aerodynamic size
- Solid diagonal lines indicate 1:1, and dashed diagonal lines indicate ± 5%.

Horizontal bars indicate the range of theoretical aerodynamic sizes that could be expected for the specific particle type, given literature values for effective density and shape factor.

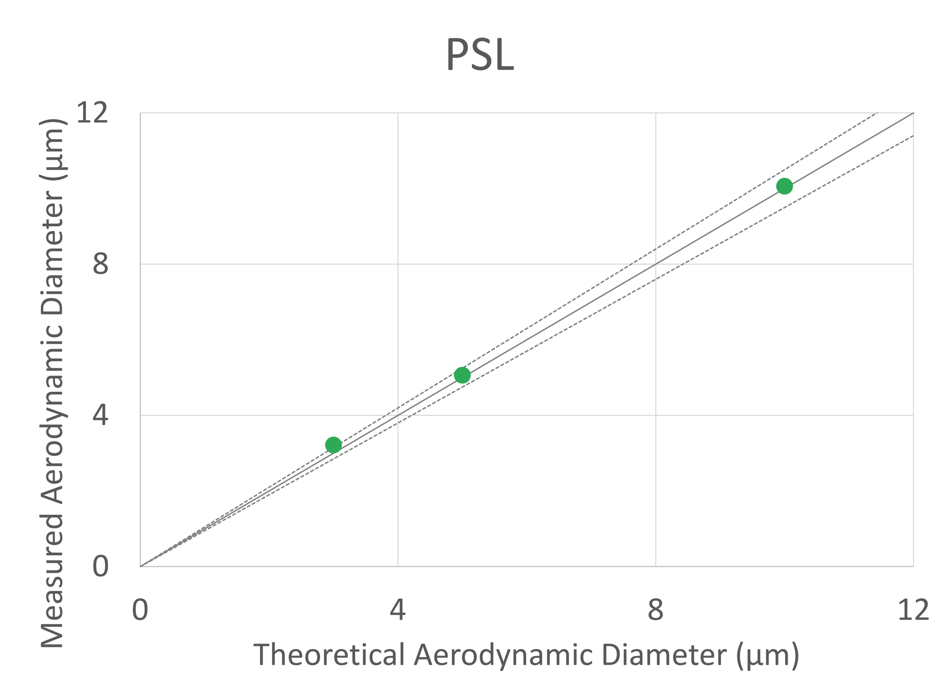

Fig. 2: Size accuracy of FMAG-generated PSL particles.

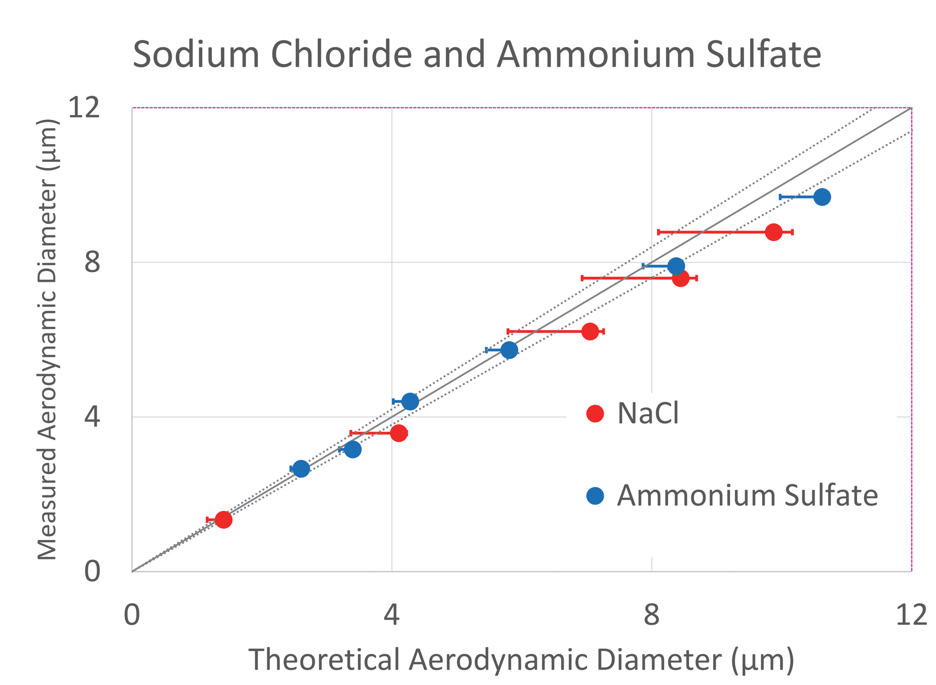

Fig. 3: Size accuracy of FMAG-generated sodium chloride and ammonium sulfate particles.

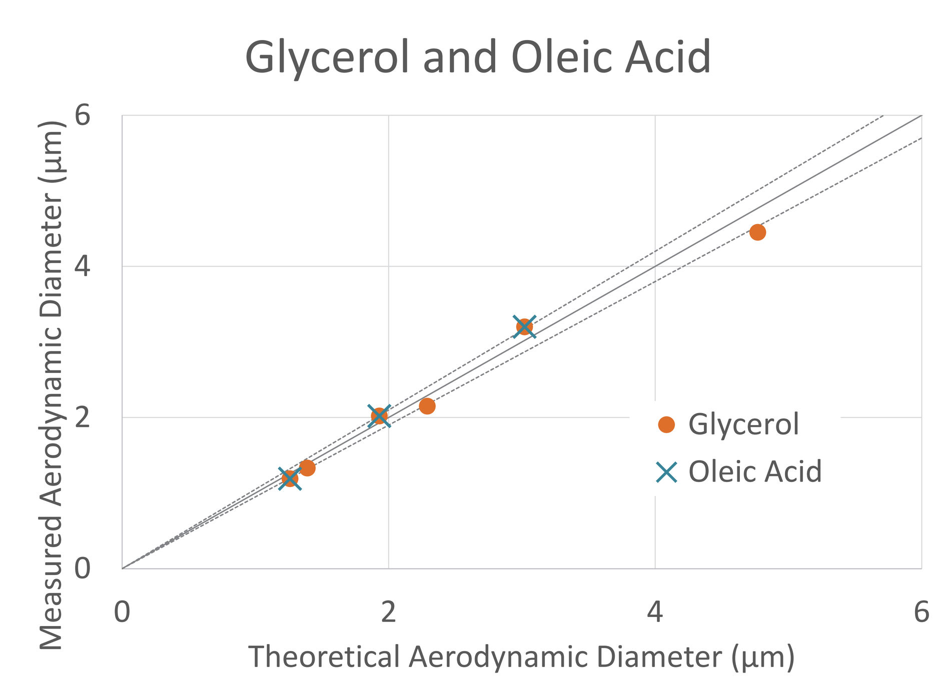

Fig. 4: Size accuracy of FMAG-generated glycerol and oleic acid particles.

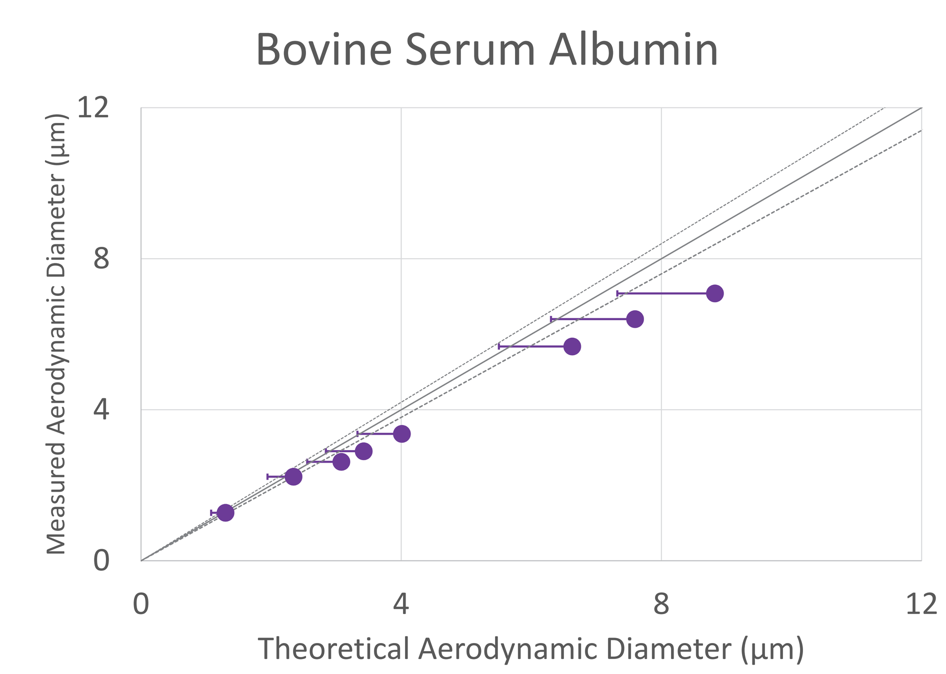

Fig. 5: Size accuracy of FMAG-generated bovine serum albumin particles.

Figures 3 & 5 demonstrate that particles made from dried solids may exhibit different aerodynamic diameters than initially expected. Applying literature values for effective density and shape factor significantly narrows the gap between prediction and measurement, illustrating the importance of those parameters.

Conclusions

- The FMAG generates liquid particles with highly accurate (<1%) volume-equivalent and aerodynamic diameters.
- Upon drying, solid particles may acquire different shape factor and/or density than initially assumed.
- Effective density and shape factor should be carefully considered when reporting aerodynamic diameter of FMAG-generated solid particles.

References

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