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True density of soot particles: A comparison of results highlighting the influence of the organic contents

F.-X. Ouf[1], S. Bourrous[1], S. Fauvel[1], A. Kort[1, 2] L. Lintis[1,3], J. Nuvoli[1,3] and J. Yon[4]

[1]Institut de Radioprotection et de Sûreté Nucléaire (IRSN), Gif-Sur-Yvette, 91192, France
[2]Ecole Nationale Supérieure des Mines, SPIN-EMSE, CNRS:UMR5307, LGF, 42023 Saint-Etienne, France
[3]Université de Lorraine, Laboratoire Réactions et Génie des Procédés (LRGP), UMR 7274, F-54000, Nancy, France.
[4]Normandie Université, INSA Rouen, UNIROUEN, CNRS, CORIA, 76000 Rouen, France.
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True density is the density of the condensed material as opposed to the bulk density (density of a porous material or containing interparticles holes). For aggregates of primary spheres, as soot for example, true density refers to the density of the primary spheres. True density of powders has been widely measured since last century using Helium pycnometry[1] and volume displacement methods such as ISO 787-23[2]. In most of the cases, within these methods, 500 mg of powder are at least needed to perform a relevant density analysis. This kind of analysis is suitable for industrial applications in the field of powder production, for which powder amount is not a limiting point. For research applications and specifically within the aerosol and soot scientific community, retrieving several hundred of milligrams of nanostructured carbonaceous particles from a burner, a diffusion flame or automotive / aircraft engines is a tremendous task. An alternative method, based on aerosol measurements (mainly based on DMA-CPMA analysis), has been recently proposed (Yon, Bescond, & Ouf, 2015).

In the present study, a validation of ISO 787-23 and DMA-CPMA methods for measuring true density on reference black carbon samples is first proposed. Figure 1 presents the comparison between measured true density and reference true density for reference samples, highlighting the ability of both ISO 787-23 and DMA-CPMA methods, for measuring this property for carbonaceous nanoparticles aggregates.

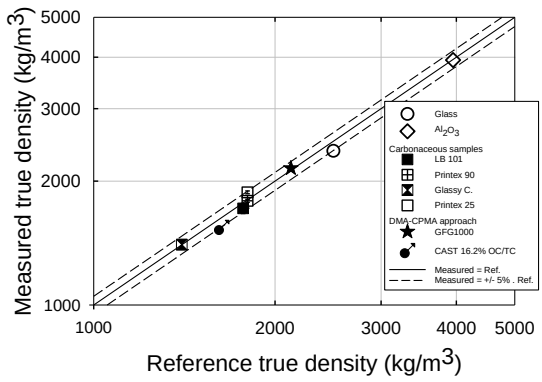

Figure 1: validation of ISO 787-23 and DMA-CPMA methods of true density measurement

Furthermore, measurements of true density on samples representative of fire emissions at different scales are also presented and discussed, according to their respective experimental uncertainties. Figure 2 presents the evolution of true density as a function of the organic carbon (OC) content, measured according to the Improve_A protocol (Chow et al., 2007) applied to the EC/OC analyzer from Sunset lab.

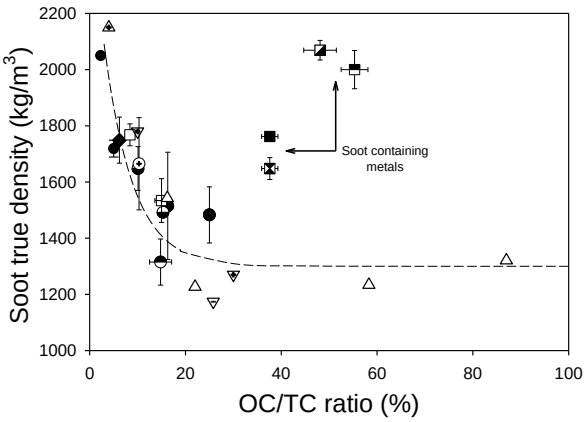

Figure 2: Evolution of soot density as a function of OC/TC ratio (dashed line is a guide to the eye)

An interesting correlation between the soot density and the OC content is observed and commented: the soot true density significantly decreases with their OC content increase. Three different ranges of densities are then proposed as a function of the OC/Total Carbon (TC) ratio of soot particles. For low OC content (i.e. less than 5%) and high OC content (i.e. more than 20%), respective mean values of 1834 +/- 187 kg/m^3 and 1285 +/- 217 kg/m^3 are proposed. For intermediate OC content values, a fitting is applied according to a mixing law. Finally, a discussion is conducted on the relevance of using these values of soot true densities for temperature representative of those reported for industrial fires and ranging from 25°C to 240°C.

Chow, J. C., Watson, J. G., Chen, L. W. A., Chang, M. C. O., Robinson, N. F., Trimble, D., & Kohl, S. (2007). *J. Air & Waste Manag. Assoc. (1995)*, *57*, 1014–1023.

Yon, J., Bescond, A., & Ouf, F.-X. (2015). *J. Aero. Sci.*, *87*, 28–37.

[1] https://www.astm.org/Standards/B923.htm
[2] https://www.iso.org/standard/5102.html