Application of a tri-thermal thermophoretic precipitator for the study of soot aggregates morphological influence on their thermophoretic behaviour.

L. AIT ALI YAHIA[1*], E.GEHIN[1] and B.SAGOT[2]

[1] *Université Paris-Est, CERTES, 61 Avenue du Général de Gaulle, 94000 Créteil, France.*
[2] *École Supérieure des Techniques Aéronautiques et Construction Automobile (ESTACA), 12 Avenue Paul Delouvrier, 78180 Montigny-le-Bretonneux.*
Keywords: Soot, Thermophoresis, aerosol deposition, fractal aggregate.
*Presenting author email: lyes.ait-ali-yahia@u-pec.fr

The capture of nano-particles such as soot aggregates produced by combustion engines is of practical importance since they represent one of the major sources of atmospheric pollution. The fact that the soot particles are transported by a high temperature combustion gas makes the thermophoresis as the most promising technique for their capture. Indeed, fine particles suspended in a gas subjected to a thermal gradient might migrate from the hot to the cold region of the gas. This particle motion is due to a driving thermophoretic force resulting from the gas molecules differential bombardment on the particle surface. This phenomenon contributes to the fouling of EGR (Exhaust Gas Recycling) systems and also to the fouling of turbine blades exposed to dust particles from combustion.

If the thermophoresis of spherical particles is well known and studied, the complex morphology and physicochemical nature of soot aggregates makes it difficult to understand their thermophoretic behaviour. Indeed, an aggregate can be characterized by its primary particles number and size and also by the fractal dimension D_f and there are limited works studying the particles morphology influence on their thermophoretic behaviour. The most recent study proposed by Brugière *et al*., (2013) shows that the soot aggregates thermophoretic velocity is mainly governed by the primary particles number confirming thus the theoretical results presented by Mackowski (2006) in a numerical study.

The main objective of this work is then to identify which of the morphological parameters influence the most the thermophoretic behaviour of soot aggregates. For that a new tri-thermal precipitator has been developed and validated in order to apply it with non-spherical soot particles. In this device, particles flow through a 1mm annular space between two concentric tubes where a thermal gradient is created by cooling the inner tube and heating the outer one. The particles will then deposit by thermophoresis on the cold tube wall. This device is based on the so-called penetration method where the deposition rate is obtained by particles concentration measurements upstream and downstream of the test section. A model developed in this study allows the deposition rate conversion into thermophoretic diffusion coefficient K_{th}.

A propane diffusion flame generator (miniCAST) was used to generate soot aggregates with a wide mobility diameter range ($20 < d_m < 200$nm). The particles produced by four miniCAST setting points were characterized in order to evaluate their morphological parameters such as the fractal dimensions D_f, the primary particles diameters d_{pp} and their number n_{pp}. These particles were after that drawn in the precipitator in order to evaluate the thermophoretic diffusion coefficient corresponding to each miniCAST setting point. The results obtained in this study are plotted in figure 1.

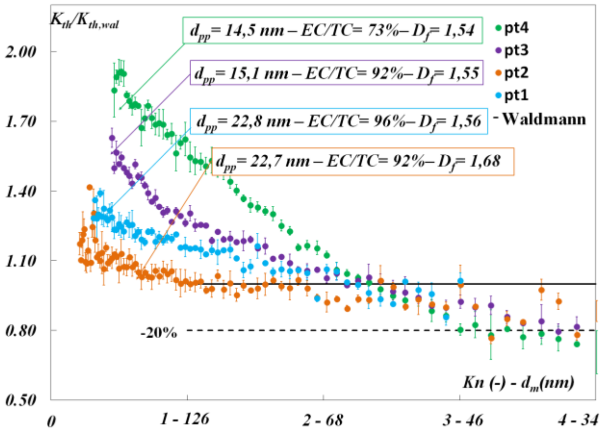

Figure 1. Evolution of the normalized thermophoretic diffusion coefficient with the Knudsen number. $K_{th,wal}$ is the Waldmann theoretical thermophoretic diffusion coefficient value for small spherical particles.

This work confirms the results presented by Mackowski (2006) and Brugière *et al*., (2013) about the increase of the aggregates thermophoretic diffusion coefficient with the dynamic mobility diameter d_m. This work shows also that the soot particles thermophoretic diffusion coefficient seems to increase with the decrease of the primary particles diameter and also with the fractal dimension decrease. The presence of organic carbon on the particle contributes also to the thermophoretic diffusion coefficient increase.

References

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