MECANIQUE ENERGETIQUE

End-of-study internship for Engineering school or Master Research students

Aerosol particles separation by means of a microfluidic thermophoretic device: numerical analysis

Context:
This Master internship is part of a French National project ANR AERATOR (2024-2027). This work is a precursor step in order to prepare for a Doctoral work. The grant for the doctoral scholarship is already available.

Localisation: IUSTI, UMR CNRS 7343 Laboratory, Marseille
Collaboration : Institut Clément Ader (ICA), UMR CNRS 5312, Toulouse
Duration: 6 months, starting date 15 February 2024
Supervisors:
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Candidate profile: Master student in Physics or Mechanical Engineering or Aerospace Engineering. Taste for numerical modeling and simulation in fluid mechanics and heat transfer, sense of innovation and autonomy. Tools: Theoretical analysis, analytical approach, use of Star-CCM+

Attachments to be provided with the application:

- CV
- Cover letter
- Recommendation letter
- Master grades

Salary:

- 600 €/month
- Financial aid for mobility will be provided for students coming from abroad (1x plane ticket)

Main topic:
Aerosols are defined as a suspension of particulate matter or liquid droplets in a gas. They come from both natural and human sources, and they can be detrimental for the environment and human health. The separation of particulate matter suspensions (aerosols particles) by means of a microfluidic device for concentration measurements and analysis is of primary importance for both indoor and outdoor applications. The aim of the ANR AERATOR project is to develop a new aerosol microfluidic separator, which operates by means of the thermophoretic principle [1] (Figure 1). The project will focus on the fluid-dynamics and micro-fabrication problematics involved in creating such a device. The microfluidic device will be able to separate different types of aerosols as a function of size, mass density and thermal conductivity of the particles. A microfluidic separator can be a strong asset to effectuate global and local concentration measurements and sensing of air pollutants or liquid suspensions carrying toxic biological agents in a very cost-effective manner in many strategic points. The obtained results will increase the scientific understanding of the aerosol transport phenomena due to

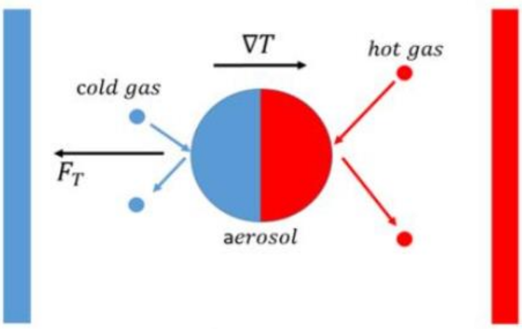

Figure 1. Thermophoretic effect on a particle

temperature gradient, which will allow improving the efficiency of particle separation equipment for ground and space applications. The different prototypes will be the first of their kind at the micro-scale (Figure 2).

Context:
Aerosols with a diameter less than 2.5 µm (PM2.5) can be deposited deep into the lungs, inducing oxidative stress and respiratory diseases. Several recent studies found that short- and long-term exposure to specific constituents, such as organic carbon, elemental carbon, sulfate, nitrate and sulfur, can be associated with increasing mortality. Studies reveal that ambient air pollution causes more than four million premature deaths per year. Furthermore, particles like black carbon (BC) and brown organic carbon (BrC) can influence climate change by absorbing solar radiation and thus changing the heat exchange balance at the atmosphere, by influencing the cloud processes, and by altering the melting of snow and ice cover. BC particles are formed mainly in flames, the major sources being diesel engines, coal burning for industrial and residential uses. Pure BC exhibits a structure similar to graphite with small-sized spherical particles of 10–50 nm of diameter and is a chemically stable and highly pollutant molecule. BrC is formed mainly by biomass burning, being the major source of burning of agricultural fields, forests and grasslands. These two products of combustion are ubiquitous in outdoor and indoor environments.

To our knowledge, efforts related to building a lab-on-a-chip thermophoretic particle separator at the microscale have been realized almost only in respect to liquid flows [2,3]. Nevertheless, very little effort has been carried out to reduce the scale of the working devices to the millimetric or micrometric scales for gas flow separators. The only work performed on the matter was realized by researchers of the University of California, Berkeley, who manufactured an air-microfluidic sensor for airborne particles (25mm x 21 mm x 2 mm footprint). Here the thermophoretic principle was used to deposit particles onto the surface of a mass-sensitive film bulk acoustic resonator (particle counter). The main stream particle separation was performed via a virtual impactor [4,5].

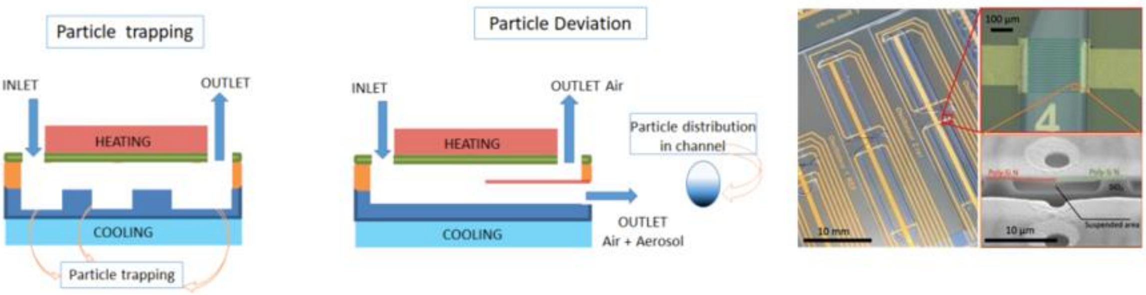

Figure 2. Left: *Illustration of different thermophoretic separator designs. Right:* optical micrograph showing micro-sensors and heaters, their connection lines and a dry-film microfluidic channel integrated on top.

Objective of the internship: Development of numerical model of the transport of aerosols in a mini channel subjected to thermal gradients in the perspective of optimizing a microfluidic separator.

Methods: The available CFD tools such as Star-CCM+ and Fluent will be used to simulate the gas flow through the channel submitted to pressure and temperature gradients. The particle tracking will be done in a Lagrangian framework. At the mesoscopic scale, the kinetic model (S-model) to the Boltzmann kinetic equation will be used to obtain the revised expressions of the thermophoretic force and the Cunningham slip correction factor for various types of gas-solid particles interaction laws. The numerical simulations obtained via forementioned approaches will allow the development of new experimental setup to measure the aerosol particles separation via themophoretic force.

This internship will allow to make the first steps in the development of the microfluidic separator.

References:

1. Saxton, R. and Ranz, W. *Journal of Applied Physics*, *23*(8), pp.917-923. 1952. doi: 10.1063/1.1702330
2. Geelhoed, P. et al.Chemical Engineering Research and Design 84.5:370-373, 2006. doi:10.1205/cherd05012
3. Choe,S. et al. *Biosensors*, *11*(11), p.464, 2021. doi: 10.3390/bios11110464
4. Paprotny, I et al. Sensors and Actuators A: Physical, 201, pp.506-516, 2013. doi: 10.1016/j.sna.2012.12.026
5. Fahimi, D. et al. Sensors and Actuators A: Physical 299 111569, 2019. doi: 10.1016/j.sna.2019.111569