Mathematical Modelling and Numerical Methods for turbulent multicomponent sprays: high-dimensionality-space moment methods

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Context

In aeronautical engines, liquid fuel is often injected directly into the combustion chamber. Because of the atomization of the liquid jet, it generates a spray of droplets that interacts with the turbulent gas phase. Realistic liquid fuels are composed of several species and therefore accounting for the multicomponent aspect is mandatory to capture the physics of the spray.

To describe this spray, two classes of methods are available in the literature: the Lagrangian tracking approach, which is interested in the evolution of each droplet (or groups of droplets) along its path, or the Eulerian moment method, which considers the spray of droplets as a continuum. The latter is of very interest because of its intrinsic statistical convergence and the shared parallel computing with the carrier gas phase.

Whereas several moment methods have been proposed in the literature for single-component sprays, no method exists for multicomponent sprays, which imposes several constraints. The first one is the curse of dimensionality: if the physical description of the droplet requires many dimensions (size, position, temperature, velocity, composition…), the number of moments can become very large. Furthermore, if the Number Density Function (NDF) of the spray is not “simple” (monodisperse, Gaussian…), the number of moments per dimension can again become very large. Thus, finding strategies for optimizing the moment list is mandatory. The second one is the structure of the temperature space: the droplet temperature is bounded by the wet-bulb temperature, which is a time-and-space varying property. Today, no moment method can handle such a varying upper bound.

Objective of the post-doctoral position

The objective of the present post-doctoral position is to investigate these two issues. The droplets will be described by size, velocity, temperature, and composition, thus requiring multi-variate moment methods. In this optics, conditioning techniques of [1] will be used. For the second issue, several options are envisaged, such as transporting the additional bound. This is however a very open question. Finally, robust, and accurate numerical schemes need to be developed, that preserve the realizability constraints on the moments, as done for example in [3] for size moments.

The candidate

The present position requires to implement methods in numerical solvers of the laboratory, the candidate must be proficient in coding. The coding will be performed in a fortran code, but preparatory implementations can be done in python or Matlab.
The candidate must have a solid background in applied mathematics, preferably with an experience in moment methods (but this is not mandatory). He will join the applied mathematics team and will interact with several researchers of the laboratory working on two-phase flows.

Bibliography

[1] C. Yuan and R. Fox, "Conditional quadrature method of moments for kinetic equation," *Journal of Computational Physics,* vol. 203, no. 22, pp. 8216-8246, 2011.

[2] A. Vié, F. Doisneau and M. Massot, "On the anisotropic Gaussian velocity closure for inertial-particle laden flows," *Communication in Computational Physics,* vol. 17, no. 1, pp. 1-46, 2015.

[3] F. Laurent and T. Nguyen, "Realizable second-order finite-volume schemes for the advection of moment sets of the particle size distribution," *Journal of Computational Physics,* vol. 337, pp. 309-338, 2017.