www.onera.fr

PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAADA-2025-30**
(à rappeler dans toute correspondance)

Lieu : Châtillon

Département/Dir./Serv. : DAAA / DEFI

Tél. : 01 46 73 48 46

Responsable(s) du stage : Alexandre Suss

Email. : alexandre.suss@onera.fr

DESCRIPTION DU STAGE

Thématique(s) : Numerical methods, simulation and high-performance computing

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Probing of lattice Boltzmann methods for compressible flows

Sujet :

Computational Fluid Dynamics (CFD) has become an essential design tool in the aeronautics industry. While most industrial-level flow simulations rely on the Reynolds Averaged Navier-Stokes (RANS) approach, this method reaches its limits when it comes to accurately characterizing unsteady turbulent flows or studying broadband aeroacoustic phenomena. To address these challenges, there is an increasing demand for high-fidelity flow simulation tools with competitive runtimes. In this context, the lattice Boltzmann method (LBM) has recently emerged as a fast and efficient alternative to the classical Navier-Stokes methods for the simulation of unsteady flows [1]. However, in its so-called "standard" formulation, the lattice Boltzmann method is restricted to the simulation of isothermal and weakly compressible flows (with Mach numbers below 0.3), and its extension to compressible flows still presents considerable challenges in terms of stability, computational cost and accuracy. Despite these obstacles, recent research efforts have led to the development of promising variants of the lattice Boltzmann method for the simulation of compressible flows, paving the way for their potential use at an industrial level [2], as illustrated in Figure 1.

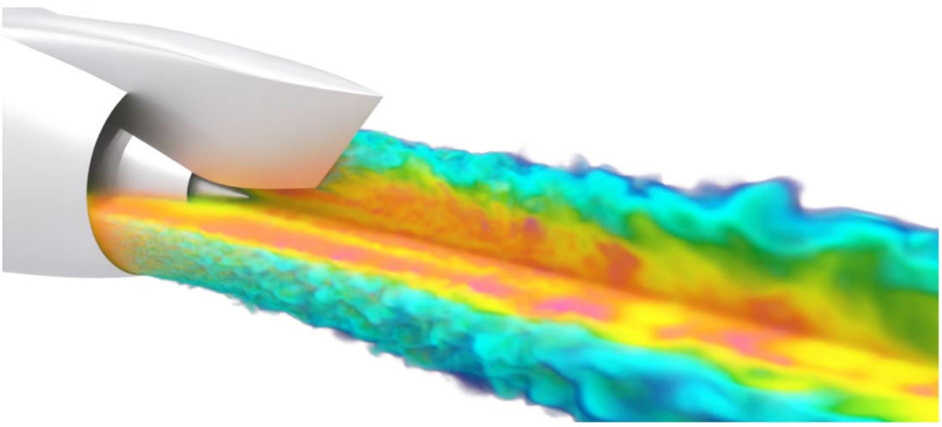

Figure 1 - Example of a computation performed with a compressible lattice Boltzmann method [3].

The aim of this internship is to conduct a comprehensive comparative study of various compressible lattice Boltzmann methods to identify their respective strengths and weaknesses, and contribute to a deeper understanding of their numerical properties.

- As a first step, the trainee will undertake an exhaustive and critical literature review of the various compressible variants of the lattice Boltzmann method available to date.

- The focus will then be placed on the so-called "hybrid" lattice Boltzmann method, which couples the LBM for solving the conservation of mass and momentum equations with a finite-difference/finite-volume scheme for solving the energy equation [4]. This approach is employed by the industrial code ProLB (http://www.prolb-cfd.com), which is used by Airbus and Safran and developed in collaboration with ONERA. This compressible approach will be evaluated through simulations on academic test cases, emphasizing its dissipation, dispersion, conservativity, stability properties, as well as its computational cost. Additionally, the impact of various numerical parameters of the model will be analyzed.

- If time permits, a comparison between the "hybrid" compressible LBM approach and traditional Navier-Stokes methods will be conducted. This will help assess the relevance of this relatively new method compared to more established approaches in the CFD community.

All this work will be carried out within ONERA's Cassiopée/FastLBM environment, combining a pre-, co- and post-processing tool for CFD and a lattice Boltzmann solver optimized for intensive computing. The trainee may also be required to use the commercial software ProLB for advanced simulations using the hybrid lattice Botlzmann approach for compressible flows.

Bibliography :

[1] Suss, A., Mary, I., Le Garrec, T., & Marié, S. (2023). Comprehensive comparison between the lattice Boltzmann and Navier–Stokes methods for aerodynamic and aeroacoustic applications. *Computers & Fluids*, *257*, 105881. https://doi.org/10.1016/j.compfluid.2023.105881

[2] Hosseini, S. A., Boivin, P., Thevenin, D., & Karlin, I. (2024). Lattice Boltzmann methods for combustion applications. *Progress in Energy and Combustion Science*, *102*, 101140. https://doi.org/10.1016/j.pecs.2023.101140

[3] Daviller, G., Charles, E., Boussuge, J. F., Renard, F., & Huber, J. (2024, June 4). Investigation of Jet-Pylon Interaction Noise Using LBM. *30th AIAA/CEAS Aeroacoustics Conference*. https://doi.org/10.2514/6.2024-3180

[4] Farag, G., Coratger, T., Wissocq, G., Boivin, P., & Sagaut, P. (2021). A unified hybrid lattice-Boltzmann method for compressible flows: Bridging between pressure-based and density-based methods. *Physics of Fluids*, *33*(8), 086101. https://doi.org/10.1063/5.0057407

Est-il possible d'envisager un travail en binôme ? Non

Méthodes à mettre en oeuvre :

☒ Recherche théorique	☒ Travail de synthèse
☐ Recherche appliquée	☒ Travail de documentation
☐ Recherche expérimentale	☐ Participation à une réalisation

Possibilité de prolongation en thèse : Oui

Durée du stage : Minimum : 5 months Maximum : 5 months

Période souhaitée : Between February and September 2025

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
Applied mathematics, numerical methods, numerical analysis, compressible fluid mechanics, programming (Python, C, Fortran)	French Engineering school and/or Master in numerical analysis, applied mathematics or fluid mechanics