PhD Thesis – Start date : 09/2026 – Duration : 36 Months

Development of Advanced Lattice-Boltzmann Simulations of Transonic and Transcritical Flows in Fatal-Heat Recovery Systems

Project Context: The REVCO$_2$ Project - PEPR SPLEEN

The intermittent nature of renewable energy sources highlights the need for diversification and optimization of energy recovery and conversion systems to ensure a stable and secure energy supply. Among potential energy sources, solar radiation, biomass combustion or gasification, geothermal heat, and industrial waste heat all play critical roles. One promising solution for harnessing these energy sources is the **supercritical CO$_2$ (sCO$_2$) Brayton cycle**, which offers high thermodynamic efficiency, compact equipment, and adaptability to a wide range of heat sources, including next-generation nuclear reactors and industrial waste heat. This PhD thesis is part of the PEPR REVCO$_2$ project, a massive collaborative effort among four research laboratories (CETHIL, Lafset, LMFA and LUSAC) to fully develop a versatile **reversible** sCO$_2$ Brayton cycle targeted to harvest industrial waste heat. In this project, LMFA focuses on global design of the turbomachinery stages.

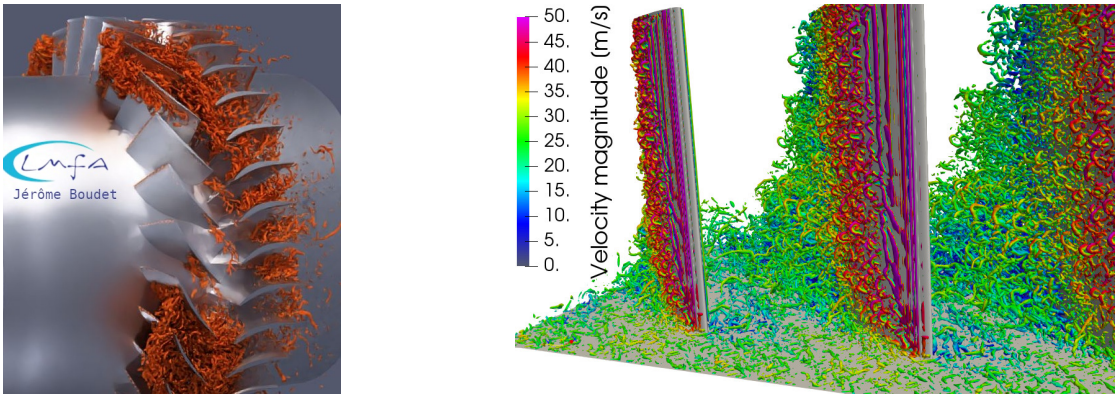
PhD thesis Objectives and Methodology

This project is built upon the expertise of the research team (see, e.g. Vienne et al., 2024; Giauque et al., 2023). The PhD work is structured around the following key milestones:

1. **Implementation and validation of real-gas model:** Develop, verify and validate real gas equations of state capable of accurately representing the supercritical behavior of CO$_2$.
2. **Assessment and improvement of the solver:** Identify the limitations of the current solver in regards to the global needs of the REVCO$_2$ project. Propose, develop, and test enhancements (e.g., shock-capturing strategies or improved numerical schemes).
3. **Idealized supersonic flow simulations:** Using the optimized code, conduct idealized simulations of supersonic real gas flows.
4. **Application to realistic configurations:** Finally, perform simulations of realistic turbomachinery configurations.

Throughout the REVCO$_2$ project, the PhD candidate will engage in exchanges with the other partners. The results obtained from the simulations of the realistic turbomachinery configurations will served as input data for the REVCO$_2$ consortium, in particular for the turbomachinery design optimization process conducted by a parallel PhD student at LMFA.

The numerical solver involved is ProLB. It is an innovative Computational Fluid Dynamics (CFD) software solution developed at LMFA in collaboration with academic and industrial partners fostering scientific breakthrough. It has already been adopted by major industrial companies. The solver is based on the **lattice-Boltzmann method** and performs inherently unsteady simulations of highly complex flows with a competitive turnaround time.



Examples of high-fidelity simulations performed with the ProLB solver.

Candidate profile

We are seeking for an Engineering or Master graduates with a strong background in **fluid mechanics and numerical flow simulation**. A significant part of the work will involve scientific programming, development of numerical methods, and in-depth physical analysis of flow phenomena. The ideal candidate is passionate about new opportunities offered by cutting-edge CFD methods. Prior experience in CFD and/or CFD code development (e.g., Python, Fortran, C++) would be a considered as a strong asset.

Selection process

The recruitment process takes place on this platform https://ecolecentraledelyon.recruitee.com:

1. Written application: CV, a cover letter, and transcripts for the current and previous academic years. One or more recommendations from teachers or supervisors would be appreciated.
2. Selection interview: in person or online.

A security clearance must be issued after acceptance.

Working environment

The PhD project will be jointly supervised by Lucien Vienne (CNRS engineer and specialist in Lattice Boltzmann Method), Alexis Giauque (associate professor at ECL and specialist in thermodynamics), and Emmanuel Leveque (CNRS research director and specialist in turbulence). The doctoral candidate will benefit from regular meetings to closely support the progress of the research. The successful candidate will join a stimulating research environment and become part of a small team working on ProLB and LBM including permanent researchers, three post-doctoral fellows and two additional PhD students.

The Laboratoire de Mécanique des Fluides et d'Acoustique (LMFA) is a major research actor on fluid mechanics in France, and is located in the campus of École Centrale de Lyon (Écully, France) close to the city of Lyon.

The gross salary is approximately €2,300 per month. In addition, 75% of the cost of the public transportation pass is covered. The position includes standard employee benefits under French law, such as paid annual leave and social security coverage.