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JOB OFFER – POST-DOCTORAL

Large-Eddy Simulation of a combustion chamber

OFFER INFORMATION

Reference: AAM-2025-DAV-02
Team: AAM

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Contact person:

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Period: 1 year – from February, 2025
Salary: 40 K€/year (gross)
Level of education required: PhD

Key words: CFD, Spectral Difference, NSCBC

CERFACS

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Cerfacs works closely with its seven partners: Airbus, Cnes, EDF, Météo France, Onera, Safran et TotalEnergies.

HOSTING TEAM - AAM

The Advanced Aerodynamic & Multiphysics (AAM) team is dedicated to developing cutting-edge numerical methods, physical modeling, and High-Performance Computing (HPC) techniques for new Computational Fluid Dynamics (CFD) solvers. The work focuses on fluid dynamics simulations for aircraft, rockets, and turbomachinery, in close collaboration with Cerfacs partners.

CONTEXT

The need for numerical simulation of unsteady multi-physical phenomena is a subject of major interest in the aerospace industry. They offer a cost-effective alternative to testing and experimentation, significantly reducing development time. It also facilitates the design and optimization of aerospace systems (combustion chambers, aerodynamic structures, etc.). To be an effective tool, the underlying simulation methods must faithfully represent the physical phenomena of interest in industrial configurations.

In this context, CERFACS is working closely with ONERA to develop innovative scientific computing methods within the JAGUAR software. JAGUAR is a high-performance computational code that solves the reactive Navier-Stokes equations in laminar and turbulent regimes using large-scale modeling. The corresponding system of equations is discretized using a high-order numerical scheme of the Spectral Difference (SD) type. This scheme is an alternative to discontinuous Galerkin methods, offering the same general properties (high order, hp refinement, native handling of non-conforming and unstructured meshes) with better performance in terms of temporal stability and computational cost.

Work carried out during Adèle Veilleux's PhD thesis [1] enabled the choice of elements to be extended to triangular and tetrahedral meshes. In parallel, the work of T. Marchal [2] enabled reactive simulations to be done on hexahedral meshes. To make the method more robust in an industrial context, recent work has stabilized the approach in the presence of shocks [3] and extended it for all polynomial orders [4]. In this post-doc, we propose to continue this work to improve the modeling possibilities for simulating reactive flows [5].

[1] A. Veilleux, G. Puigt, H. Deniau and G. Daviller. S*table Spectral Difference Approach Using Raviart-Thomas Elements for 3D Computations on Tetrahedral Grids*. Journal of Scientific Computing, 91, 2022.

[2] T. Marchal, H. Deniau, J.-F. Boussuge, JF., B. Cuenot and R. Mercier. *Extension of the Spectral Difference Method to Premixed Laminar and Turbulent Combustion*. Flow Turbulence and Combustion, 111, 2023.

[3] N. Messai, G. Daviller and J.-F. Boussuge. Artificial viscosity-based shock capturing scheme for the Spectral Difference method on simplicial elements. Journal of Computational Physics, 2024.

[4] N. Messai and G. Daviller. *A corrected Raviart-Thomas Spectral Difference scheme stable for arbitrary order of accuracy on triangular and tetrahedral meshes.* To appear in Computer Methods in Applied Mechanics and Engineering. 2025.

[5] L. Gicquel and G. Staffelbach and T. Poinsot. *Large Eddy Simulations of gaseous flames in gas turbine combustion chambers*. Progress in Energy and Combustion Science, 38, 2012.

MISSION

This post-doctorate will have two main objectives. The first is to develop non-reflective boundary conditions for triangular and tetrahedral meshes. These boundary conditions are of crucial interest for solving problems in combustion, internal aerodynamics, and aeroacoustics. While the NSCBC method is well known for classical numerical methods (DG, FV, etc.), its extension to tetrahedral SD schemes is not trivial and requires dedicated mathematical and computational development. It will also be possible to consider modifications to the construction of the SD scheme to facilitate the incorporation of this boundary condition. For example, the solution basis could be modified to impose the boundary condition in the strong form, thus simplifying its implementation.

Secondly, we will generalize the numerical scheme to prismatic elements to accurately resolve parietal flows in the presence of boundary layers. These mesh elements make it easy to take into account the anisotropy of the flow. To do this, we need to determine polynomial bases with good approximation properties that preserve the stability of the scheme. Once this development is complete, we'll turn our attention to improving the method in the case of mixed meshes (composed of prisms and tetrahedrons). These mixed meshes make it possible to discretize the geometries of complex problems while optimizing the algorithmic cost of resolution. What's more, the interfaces between these elements are known to generate numerical noise that heavily pollutes aeroacoustic simulations. This problem, which is common to all discontinuous high-order schemes, is currently an obstacle to the use of these methods for these applications of interest. Riemann solvers are suspected of being the cause of the problems observed.

Despite this initial intuition, it will be necessary to analyze the root cause of the problem to devise a digital workaround that cancels out the observed error. Once these methodological building blocks have been developed, the effectiveness and robustness of the method will be validated on academic and then industrial configurations.

DESIRED PROFILE

- PhD in CFD, numerical analysis, or applied mathematics defended less than 3 years ago.
- The candidate must know about CFD, fluid mechanics, and applied mathematics.
- In particular, skills in acoustics and combustion are a plus.
- The candidate will be required to present his/her work orally and in writing in English, according to the standards expected in an international research laboratory.

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