Improved LPS-POD-ROM for LES of non-isothermal turbulent flows FEF 2017 (MS submission code 8)

Samuele Rubino* and Mejdi Azaïez†

* I2M – Institut de Mécanique et d'Ingénierie (UMR CNRS 5295)
Université de Bordeaux
Site ENSCBP, 16 Avenue Pey Berland, 33607 Pessac cedex, France
e-mail: srubino@u-bordeaux.fr

† I2M – Institut de Mécanique et d'Ingénierie (UMR CNRS 5295)
Université de Bordeaux
Site ENSCBP, 16 Avenue Pey Berland, 33607 Pessac cedex, France
e-mail: mejdi.azaiez@enscbp.fr

ABSTRACT

In this work, we introduce improved Reduced Order Models (ROM) for thermally coupled turbulent flows. These non-linear closure models are inspired from successful numerical stabilization techniques used in Large Eddy Simulation (LES) of turbulent flows, such as Local Projection Stabilization (LPS), which may be cast in the Variational Multi-Scale (VMS) framework [2], and constitutes low-cost, accurate solvers (of optimal error order) for incompressible flows, despite being only weakly consistent [1].

We propose to apply a LPS finite element method to standard ROM created by Proper Orthogonal Decomposition (POD) of flows with Galerkin projection, to improve the numerical stability as well as the physical accuracy of the POD-ROM approximation.

We aim to propose a multi-level method [4] for an efficient numerical discretization of the resulting strongly non-linear LPS-POD closure model that compared with a brute force computational approach attains the same level of accuracy while clearly reducing the CPU time.

Although LPS-POD closure model is developed to derive a low-order approximation of complex non-isothermal turbulent flows, as first step we analyse it for convection-dominated convection-diffusion-reaction equations [3], by mainly deriving the corresponding error estimates.

Preliminary numerical simulations and results of benchmark flows confirm the increased numerical stability and physical accuracy of the new LPS-POD-ROM over the standard one. The computational efficiency of the proposed model is also showcased.

REFERENCES

[1] N. Ahmed, T. Chacón Rebollo, V. John, and S. Rubino, "Analysis of a full space-time discretization of the Navier-Stokes equations by a Local Projection Stabilization method", *IMA J. Numer. Analysis*, Published online, pp. 1–31, (2016).

[2] N. Ahmed, T. Chacón Rebollo, V. John, and S. Rubino, "A review of variational multiscale methods for the simulation of turbulent incompressible flows", *Arch. Comput. Methods Engrg.*, Published online, pp. 1–50, (2015).

[3] T. Iliescu and Z. Wang, "Variational multiscale proper orthogonal decomposition: convection-dominated convection-diffusion-reaction equations", *Math. Comput.*, Vol. **82**, pp. 1357–1378, (2013).

[4] Z. Wang, I. Akhtar, J. Borggaard, and T. Iliescu, "Two-level discretizations of nonlinear closure models for proper orthogonal decomposition", *J. Comput. Phys.*, Vol. **230**, pp. 126–146, (2011).