Type d'offre : Corporate offer

Post date : 18.02.25

ASNR

PostDoc - Volume Forcing and ML Methods for Synthetic Turbulence Generation: Application to Hybrid RANS/LES Methods

Informations générales

Contract type : Fixed-term contract

Contract length : 18 months

Contact :

Fabien Duval / **Aubin Brunel**

Starting date : Sun 01/06/2025 - 12:00

The [Autorité de Sûreté Nucléaire et de Radioprotection](#) (ASNR) is an independent administrative authority created by the law of May 21, 2024 on the organization of nuclear safety and radiation protection governance to meet the challenge of revitalizing the nuclear industry. Acting on behalf of the French government, it oversees civil nuclear activities in France, and carries out expert appraisal, research, training and public information missions.

Détail de l'offre (poste, mission, profil) :

Scientific context

The post-doctoral candidate will join the « Laboratoire de l'Incendie et des Explosions » (LIE). LIE focuses on fire and explosion modeling and develops software dedicated to simulating these phenomena. This research work will be carried out in collaboration with the « Calcul Intensif et Mécanique des Fluides » research group, which is part of the « Centre de Mise en Forme des Matériaux » (CEMEF, Mines Paris PSL).

LIE develops in C++ the open-source CALIF3S software, that deals with finite-volume staggered schemes for fluid flows simulations. In particular, the software includes Navier-Stokes solvers and turbulence modeling based on « Large Eddy Simulation » (LES) or « Reynolds-averaged Navier-Stokes »(RANS) statistical approaches. While the latter approach has the advantage of being less computationally expensive, its accuracy is known to depend on the quality of the turbulence model. The former approach is usually much more predictive but the computation times may become prohibitively expensive for many cases of interest. In this context, CALIF3S integrates hybrid RANS/LES methods. The latter attempts to take advantage of both approaches but requires an additional method to generate fluctuations in transition zones.

The aim of the post-doctoral work is to combine these hybrid methods with new machine-learning techniques. This work will benefit from the expertise of the CEMEF teams in the field of coupling numerical simulations for fluid mechanics and artificial intelligence. More specifically, two machine learning libraries, developed by CEMEF in Python and based on a Pytorch backend, will be made available for this work. The

post-doc will have access to the computing resources of LIE (TGCC andGENCI clusters for massively parallel computing) as well as of those of CEMEF (Pierre Laffitte clusterand dedicated GPU nodes).

Mission

A possible strategy for hybrid RANS/LES methods is to restrict the LES approach to specific regions of the computational domain where the RANS approach is considered less reliable. In some situations, the domain can be restricted to LES computations only, provided that an equivalent boundary condition is defined, e.g., modeling the region upstream from the region of interest; this corresponds typically to the « notional nozzle » approach employed for the simulation of under-expanded jets (e.g., [5]). In other situations, so-called zonal or seamless hybrid RANS/LES methods are used. Whichever strategy is chosen, in the absence of hydrodynamic instabilities naturally present in the computational domain, or when these instabilities are not sufficiently resolved, the quality of LES predictions depend strongly on the velocity fluctuations prescribed in the boundary conditions or in the RANS/LES transition zone.

The goal of the post-doctoral work is to develop a machine learning method for generating turbulent fluctuations, which may be represented as random Fourier modes and can be used either for boundary condition strategies or through volume forcing in the RANS/LES overlap area. The latter approach hasalready been used to maintain turbulence and to generate fluctuations in the RANS/LES transition [4],[3]. The first step will be to adopt a technique aimed at optimizing the free parameters of a synthetic signal based on target statistical properties (mean velocity, turbulent kinetic energy, …) available in open databases (e.g. [1]) downstream of the boundary layer. The shape of the energy spectrum, the pulsation frequency, and the number of Fourier modes characterizing the synthetic signal will be of particular interest. The resulting fluctuations will then be implemented in the context of prescribed boundary conditions on academic cases from the literature. A dynamic control approach will be then employed for equivalent boundary conditions and volume forcing for the RANS/LES transition area. The performance of the proposed method will be evaluated according to several criteria, such as there sulting simulation quality, the extent of the "gray" zone between the zones fully resolved by a RANS and LES approach, or the additional cost induced by the forcing method.

References

[1] Johns Hopkins Turbulence Databases. https://turbulence.pha.jhu.edu.

[2] P. Garnier, J. Viquerat, J. Rabault, A. Larcher, A. Kuhnle, and E. Hachem. A review on deepreinforcement learning for fluid mechanics. Computers Fluids,, 225, 2021.

[3] J. Janin. Forçage volumique basé sur une méthode de type reconstruction pour un modèle defermeture algébrique hybride RANS/LES. PhD thesis, Aix-Marseille University, 2023. Thèse dedoctorat dirigée par Pierre Sagaut, Christophe Friess, et Fabien Duval. Sciences pour l'ingénieur.

[4] J. Janin, F. Duval, C. Friess, and P. Sagaut. A new linear forcing method for isotropic turbulencewith controlled integral length scale. physics of fluids. Physics of Fluids,, 33:4, 2021.

[5] E. Papanikolaou, D. Baraldi, M. Kuznetsov, and A. Venetsanos. Evaluation of notional nozzleapproaches for cfd simulations of free-shear under-expanded hydrogen jets. International Journalof Hydrogen Energy, 37(23):18563–18574, 2012.

[6] A. Patil, J. Viquerat, A. Larcher, G. El Haber, and E. Hachem. Robust deep learning for emulatingturbulent viscosities. Physics of Fluids, 33(10):105118, 10 2021.

URL de l'offre : https://www.dataia.eu/sites/default/files/OffrePostDocMITI.pdf

Lien vers l'offre sur le site dataia.eu :https://da-cor-dev.peppercube.org/node/1238