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PROPOSITION DE POST-DOCTORAT

Title : Data assimilation of aero-optical measurements for thermal flow reconstruction

Référence : PDOC-DMPE-2020-03
(à rappeler dans toute correspondance)

Starting date: January 2021

Application deadline:

Duration: 12 month, may be renewed – Net salary : approx 25 k€ / year

Keywords: Data assimilation, fluid mechanics, aerodynamic and aerothermal turbulence, Background Oriented Schlieren (BOS)

Requirements: PhD in Fluid Mechanics or Applied Mathematics, skills in data assimilation techniques, knowledge in turbulence models for thermal flows would be appreciated, publishing experience.

Post-doctoral project, context and objectives :

Thermal and compressible flows are characterized by inhomogeneous density fields that are usually difficult to measure. One experimental technique aiming at measuring instantaneous and averaged 3D density fields is the 3D Background Oriented Schlieren (3DBOS), developed at ONERA over the past ten years [1]. This technique relies on the visualization of a textured background using a camera. The flow of interest is placed in-between, inducing aero-optical effects and apparent displacements of the textured background. Correlation algorithms can then be used to evaluate apparent displacement maps that are related to light ray deviations induced by gradients of refractive index associated with the flow. Using multiple cameras placed with different point of views, a 3D reconstruction of the density field can be achieved using a tomographic algorithm. This approach was shown to be adequate to study free shear flows such as jets [2] where boundary conditions and cameras positions are straightforward to set. In more complex configurations such as jets in cross-flow or jets impinging on a plate for instance, the technique is more difficult to implement, yielding potentially erroneous reconstructions.

A promising way to gain access to 3D density fields and to overcome the current limitations of 3DBOS may be found in data assimilation techniques aiming at providing numerical simulations closely resembling the experimental data [3]. Such numerical results calibrated on available measurements and sometimes referred to as hybrid flows are governed by equations of motions and are constrained by well controlled boundary conditions. They thus provide a priori physical solutions, enforcing correct symmetries and giving access to quantities that were not initially probed during the experiments. Recent efforts have been mainly focusing on using surface pressure measurements and velocity maps estimated using PIV (Particle Image Velocimetry) to produce hybrid flow fields for purely aerodynamic configurations [4]. The present project aims at building on such works by investigating the capability of data assimilation to produce hybrid aerothermal flow fields by assimilating displacement maps obtained by BOS using several cameras.

The configuration of interest will be a hot jet in a cross-flow at ambient temperature for which a database composed of Reynolds-Averaged Navier-Stokes (RANS) simulation results, Large Eddy Simulation (LES) results, PIV measurements and BOS displacement maps is already available. The post-doctoral project will focus on the restitution of mean (stationary) flow fields of such a jet using RANS models. Various aerothermal turbulence models will be investigated and a particular emphasis will be given on the choice of forcing or calibration parameters that should be considered to provide satisfactory hybrid flows. These parameters should encompass turbulence models parameters, boundary conditions and uncertainties on cameras parameters. Data assimilation will be performed by comparing the displacement maps obtained by BOS with the synthetic ones evaluated on each camera by raytracing through the computation volume. Since adjoint models are not available in the present set of tools, stochastic assimilation techniques will be preferred over variational ones. Given the large dimension of the problem, a particular attention will be given to approaches based on (but not restricted to) Ensemble Kalman Filters (EnKF) [5] and iterative versions developed for inverse problems [6] in order to assess their relevance and limitations for the present objectives.

[1] Nicolas et al. "A direct approach for instantaneous 3D density field reconstruction from background-oriented schlieren (BOS) measurements." Experiments in Fluids 57, no. 1 (2016): 13.

[2] Nicolas et al. "3D reconstruction of a compressible flow by synchronized multi-camera BOS." Experiments in Fluids 58.5 (2017): 46.

[3] Foures et al. "A data-assimilation method for Reynolds-averaged Navier–Stokes-driven mean flow reconstruction." Journal of Fluid Mechanics 759 (2014): 404-431.

[4] Symon et al. "Data assimilation of mean velocity from 2D PIV measurements of flow over an idealized airfoil." Experiments in Fluids 58.5 (2017): 61.

[5] Roth et al, "The Ensemble Kalman filter: a signal processing perspective" EURASIP Journal on Advances in Signal Processing (2017) 2017:56

[6] Iglesias et al, “Ensemble Kalman methods for inverse problems” Inverse Problems 29 (2013) 045001

External collaborations : No

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