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PROPOSITION DE SUJET DE THESE

Intitulé : Advanced unsteady simulations of transitional flows for aerospace and defence applications

Référence : **MFE-DAAA-2021-08**
(à rappeler dans toute correspondance)

Laboratoire d'accueil à l'ONERA :

Domaine : Mécanique des Fluides — Lieu (centre ONERA) : Meudon

Département : Département Aérodynamique, Aéroélasticité et Acoustique

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Sujet : Turbulence is ubiquitous in flows encountered in the aerospace industry because of the high values taken by the Reynolds number. It must be finely described for the prediction of problems such as dynamic loading of the wall (broadband excitation, structural integrity), buffet, inlet buzz, compressor surge (operational limits) or acoustics (stealth, noise pollution). Direct Numerical Simulation (DNS) of all scales of turbulent fluctuations in their full complexity is generally without reach of applied aerodynamics because of its prohibitive computational cost. The RANS averaged approaches may on the contrary represent in a satisfying manner the mean effects of turbulence at a low computational cost in numerous cases, which enables their routine use for design processes. Nevertheless, the RANS models do not have a sufficient degree of universality to successfully handle all possible flow configurations, and are in addition unable, by construction, to resolve the turbulent fluctuations and hence the associated unsteady content needed to finely predict the above mentioned problems.

These problems may be addressed by resolving the large scales of turbulent fluctuations (LES simulation) in the zones of interest of the flow, while sparing computational cost thanks to the use of the RANS approach in the rest of the flow. For this purpose, ONERA has developed since 2002 a hybrid RANS/LES method called ZDES [1]. This technique enables a fine resolution of turbulence in the regions studied without making the computational cost prohibitive although the Reynolds number of the considered problem is kept, for instance a wide-body aircraft in cruise conditions as illustrated by Figure 1 where a DNS would be impossible. The ZDES approach is now both established in the academic world [2] and used by the major companies of the French aeronautic sector as a high-fidelity computational tool for industrial risk mitigation ([3], Dassault Aviation, MBDA, Airbus). The method has been recently improved [4] for a better automatic detection of the zones that should be treated in RANS or in LES.

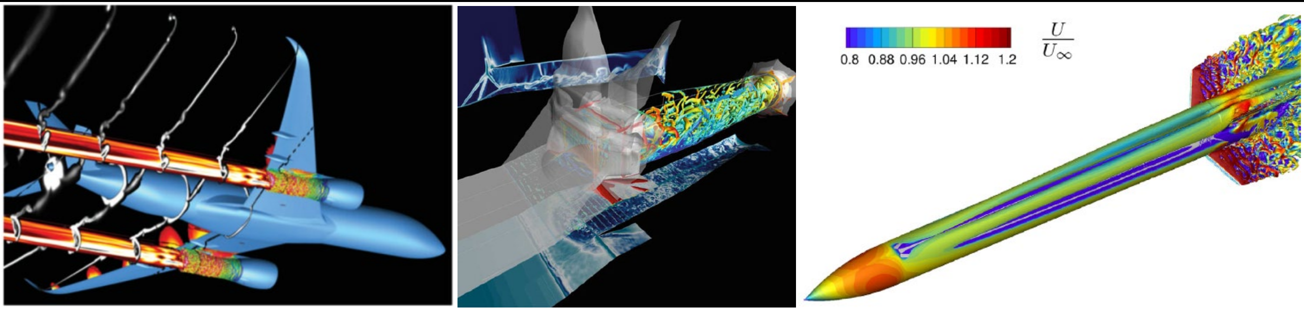

Figure 1: Examples of applications of the ZDES technique to complex geometries (wide-body aircraft [3], generic supersonic inlet [7] and generic missile [8]).

In its general form, the ZDES technique is dedicated to fully turbulent flows, which is relevant given the high values of the Reynolds number in situations where ZDES enables a strong reduction of computational cost compared with DNS. However, numerous aeronautical applications are confronted with the laminar – turbulent transition phenomenon and include transitional regions as sketched in Figure 2. To name just a few examples, this is the case for turbomachines, UAV wings, helicopter rotor blades, laminar wings in the transonic regime (airliner, cruise missile). ONERA has achieved cutting-edge RANS modelling of transitional regions [6], and a few particular cases of such regions have already been simulated by ZDES. In this context, the aim is to develop the capacity of the ZDES approach to handle in a general way the flows featuring transitional regions.

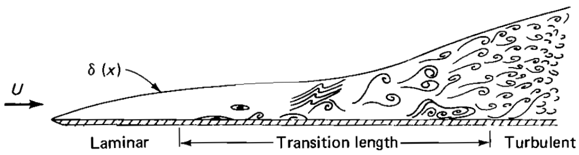

Figure 2: Illustration of a transitional region in a flat plate boundary layer [5].

The PhD objective is to develop a new mode of ZDES dedicated to the resolution of the fluctuating field in the separated transitional regions. Emphasis will be put on the fluctuations developing in the detached area, on the activation of the underlying turbulence model as well as on the use of a subgrid-scale model suited for transitional flows in the LES regions. This will involve the theoretical study of transitional flows followed by the derivation and adjustment of sensors and models adapted to ZDES, relying on the existing experiments, DNS and stability analysis.

The developments of the transitional ZDES will be implemented in an ONERA solver and then validated with test cases of increasing complexity and representative of the wing of an air vehicle, in order to demonstrate the performance of the new model in applicative situations relevant to the industry. A high-level physical analysis of the fluctuations resolved by ZDES will validate the method at each step and document its added-value in comparison with the averaged approaches.

[1] Deck, S., Recent improvements in the Zonal Detached Eddy Simulation (ZDES) formulation, *Theoretical and Computational Fluid Dynamics*, 2012, 26, 523-550
[2] Deck, S.; Renard, N.; Laraufie, R. & Weiss, P.-É., Large scale contribution to mean wall shear stress in high Reynolds number flat plate boundary layers up to Re_θ =13650, *Journal of Fluid Mechanics*, 2014, 743, 202-248
[3] Deck, S.; Gand, F.; Brunet, V. & Khelil, S. B., High-fidelity simulations of unsteady civil aircraft aerodynamics: stakes and perspectives. Application of Zonal Detached Eddy Simulation (ZDES), *Philosophical Transactions of the Royal Society A*, 2014, 372, 20130325
[4] Deck, S. & Renard, N., Towards an enhanced protection of attached boundary layers in hybrid RANS/LES methods, *Journal of Computational Physics*, 2020, 400, 108970
[5] White, F. M., *Viscous Fluid Flow*, McGraw-Hill, 1991, 1974 (2nd Ed.)
[6] Bernardos Barreda, L. F., *Modélisation de la transition vers la turbulence d'une couche limite décollée*, Thèse de Doctorat, Sorbonne Université Sciences, 2019
[7] Weiss, P.-E. & Deck, S., *Advanced Numerical Strategy for the Prediction of Unsteady Flow Aerodynamics Around Complex Geometries*, 7th Symposium on Hybrid RANS-LES Methods, 2018
[8] Manueco, L.; Weiss, P. & Deck, S., On the coupling of wall-model immersed boundary conditions and curvilinear body-fitted grids for the simulation of complex geometries, *Computers and Fluids*, 2021, 226, 104996

Collaborations extérieures : Non

PROFIL DU CANDIDAT

Formation : Master 2 ou ingénieur + master 2

Spécificités souhaitées : Formation solide en mécanique des fluides (théorie, en particulier turbulence, et méthodes numériques). Goût pour l'analyse physique et pour la programmation.