PROPOSITION DE SUJET DE THESE

Intitulé : Robust and efficient mesh adaptation for 3D RANS flows in turbomachinery

Référence : **MFE-DAAA-2022-12**
(à rappeler dans toute correspondance)

Début de la thèse : 01/10/2022	**Date limite de candidature :** 01/06/2022

Mots clés

Turbomachinery, CFD, mesh adaptation, feature-based, goal-oriented, uncertainty quantification, global sensitivity analysis

Profil et compétences recherchées

In the last year of a Research Master or Engineering School, you have notions in fluid mechanics and ideally in aerodynamics. You show an interest in aeronautics, research and innovation. You have a taste for digital and programming and have notions of Python, fortran and c++. You demonstrate a good sense of critical analysis and autonomy allowing you to adapt quickly to a technically demanding work environment.

Présentation du projet doctoral, contexte et objectif

CFD is today the best way to simulate numerically and understand fluid mechanics phenomena. The recent evolution of the computing capabilities as well as the numerical methods has opened new possibilities with a rise in the ambitions in terms of flow complexity. One of the levers to push these capabilities is to improve the mesh used to discretize the calculation domain. Indeed, the CFD solvers efficiency and accuracy are tightly linked to the meshes to which they are coupled. Furthermore, if one wants to be able to capture very fine physics such as shock waves, boundary layers or any local gradients in the flow physics, a very fine discretization would be needed to a level which is unaffordable today for complex flows, especially when unstructured isotropic approaches are considered. Fortunately, most calculations today are not performed to capture the whole physics, but target specific quantities (global efficiency, pressure recovery, friction drag…) or phenomena as pre-cited. Therefore it makes sense that according to the need a specific mesh should be generated focusing on the driving processes. This is why feature-based and goal oriented approaches have been developed [1][2][3][4]. The research centers as well as the aeronautical industries invest a growing effort toward developing and improving such methods as they are foreseen as the best solution to improve CFD capabilities for complex configurations.

The main objective of this thesis will be to develop and demonstrate the effectiveness and robustness of an automated numerical unstructured mesh adaptation technique for 3D RANS CFD calculations applied to turbomachinery configurations. To reach such an ambitious objective multiple aspects will have to be considered. Also, prior to any decision making, a thorough bibliographical study will have to be initiated and continued during the whole thesis period to be able to take benefit of the knowledge and experience already disseminated within the mesh adaptation community.

First, the adaptation will be tested for its capability of capturing three dimensional physical phenomena of interest (shock waves, wakes and separations…) using feature-based but also put into practice a goal oriented process to provide accurate calculations with regard to specific functions of merit (isentropic efficiency, pressure recovery, mass flow…). Once the mesh adaptation using these two methods has proved to be functional for turbomachinery cases (implying all periodicity requirements), a work on defining the most relevant metrics to assess the convergence level of the adaptation process through detailed physical phenomena analyses will be performed. Different techniques will be used ranging, for example, from global error indicators to flow features snapshot convergences.

As in performance evaluation as well as in design processes of turbomachinery, not only are we interested in a single functioning condition but whole characteristics, the most efficient strategy to provide adapted mesh for accurate calculations on a full characteristic will have to be found. This could have significant consequences on changing what are considered today as best practices for which the mesh is frozen for a given geometry.

Finally as, a study on how the adaptation can be made more robust when undergoing epistemic as well as aleatory uncertainties will be lead. Indeed, concerning the first kind of uncertainties, the adaptation method will be using parameters which values will have to be calibrated. This calibration can be done using both uncertainty quantification & propagation and global sensitivity analysis. Regarding the second kind of uncertainties, it will be of interest to evaluate to what extent mesh adaptation can be sensitive to flow variations as well as geometry definition imperfections as they are usually both provided a range of uncertainty.

The adaptation workflow will comprise up-to-date HPC compliant modular tools enabling their use on complex cases based on ONERA elsA unstructured solver capabilities and in house adaptation tools. Furthermore, the goal oriented approach will call upon the discrete adjoint capabilities of the solver. New specific measures of merit and their respective sensitivities will be developed if needed.

References

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[3] D. A. Venditti and D. L. Darmofal, “Anisotropic grid adaptation for functional outputs: Application to two-dimensional viscous flows,” J. Comput. Phys., vol. 187, no. 1, pp. 22–46, 2003, doi: 10.1016/S0021-9991(03)00074-3.

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Collaborations envisagées

Laboratoire d’accueil à l’ONERA

Département : Département aérodynamique, aéroélasticité, acoustique

Lieu (centre ONERA) : Meudon/Châtillon

Contact : Julien Marty, Itham Salah el Din

Tél. : 01 46 73 43 55 Email : julien.marty@onera.fr, itham.salah_el_din@onera.fr

Directeur de thèse

Nom : Marty Julien

Laboratoire : ONERA/DAAA/H2T

Tél. : 01 46 73 43 55

Email : julien.marty@onera.fr

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