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PROPOSITION DE STAGE EN COURS D'ETUDES

Référence : **DAAA-2025-39**
(à rappeler dans toute correspondance)

Département/Dir./Serv. : DAAA / ACI

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DESCRIPTION DU STAGE

Thématique(s) : Exploitation de données expérimentales et numériques

Type de stage : ☒ Fin d'études bac+5 ☒ Master 2 ☐ Bac+2 à bac+4 ☐ Autres

Intitulé : Study of energy-based methods for the analysis of irreversible performance losses

Sujet : Numerical simulations in the aeronautical field are becoming increasingly accurate and robust, enabling us to calculate flows in complex configurations. The results of these simulations therefore require adapted post-processing codes, which are evolving in parallel. ONERA is developing a post-processing code based on an exergy approach which allows the performance analysis of numerical simulations of complex flows [1]. The approach is based on the two principles of thermodynamics, and provides a formulation for dealing with disruptive configurations (Boundary-Layer Ingestion, Open fan, ...). Recent works in particular allowed to extend the validity of the exergy-based analysis to turbomachinery flows, with different levels of decomposition [2,3].

The exergy balance formulations in use at ONERA were derived in addition to other power-based methods in the literature. Some of these formulations also rely on exergy [4], with a different decomposition of its various components. Others rely on different physical quantities, such as mechanical energy [5] (to investigate external aerodynamic configurations) or euergy [6] (which is the potential of mechanical work recovery, used for cooled turbine performance analyses). The exact links between such balances, based on different physical quantities, is not always direct. Detailed investigations are therefore required in order to establish such links and to accurately identify the advantages/drawbacks of each decomposition. A particular domain for such comparisons is turbomachinery cases with significant heat transfers.

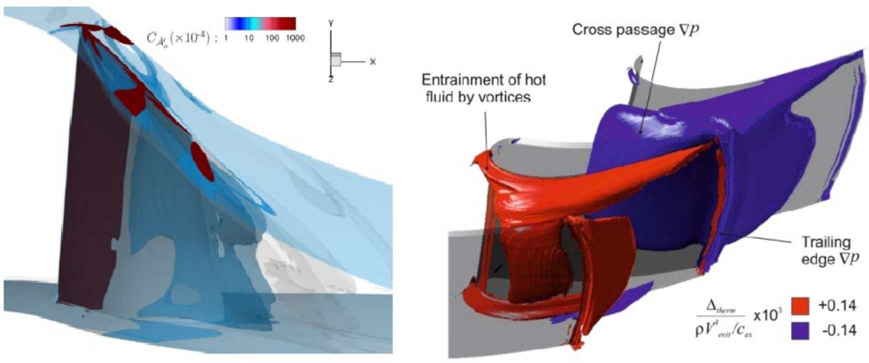

Figure 1: Iso-surfaces of irreversible exergy loss due to viscous effects [3] (left, exergy balance) and thermal creation due to heat transfers across pressure gradients [6] (right, euergy balance)

The aim of the internship will be to analyse the results given by the different formulations, and provide additional physical insights regarding the different decompositions investigated. First, a theoretical investigation will be performed in order to better interpret the differences between the exergy and euergy balance formulations. At a second step, CFD simulations of a flow field around an aerodynamic body (e.g. 2-D airfoil) and inside a cooled turbine will be performed. The numerical results will be post-processed with the exergy-based analysis tool FFX of ONERA [1] to compute exergy and euergy balance components and to compare the results obtained with each approach. Finally, the results obtained will be used to provide physical insight into the interpretation of the different balance components. Depending on the results, improvements of the approach used at ONERA may be proposed.

Through this research the intern will acquire a valuable experience in the numerical simulation of turbomachinery flows and a state-of-the-art method enabling a better understanding and quantification of the physical phenomena that dominate internal flows. This work is a contribution towards more efficient aircraft engines

[1] A. Arntz. Civil aircraft aero-thermo-propulsive performance assessment by an exergy analysis of high-fidelity CFD-RANS Flow Solutions. PhD thesis, Lille 1 University - Sciences and Technologies, 2014.https://hal.archives-ouvertes.fr/tel-01113135

[2] I. Berhouni, D. Bailly, and I. Petropoulos. Exergy balance extension to rotating reference frames: Application to a propeller configuration. AIAA Journal, 61(4):1790–1806, 2023. https://doi.org/10.2514/1.J062216 & https://hal.science/hal-03945738/.

[3] I. Berhouni, I. Petropoulos, and D. Bailly. Exergetic analysis of the NASA Rotor 37 compressor test case. In 15th European Conference on Turbomachinery Fluid dynamics & Thermodynamics (ETC15), 2023. https://hal.science/hal-04099251.

[4] M. Á. Aguirre. Exergy analysis of innovative aircraft with aeropropulsive coupling. PhD thesis, 2022. http://www.theses.fr/2022ESAE0008.

[5] M. Drela. Power Balance in Aerodynamic Flows. AIAA Journal, 47(7):1761–1771, 2009. https://doi.org/10.2514/1.42409 & https://dspace.mit.edu/handle/1721.1/108322.

[6] R. J. Miller. Mechanical work potential. In Proceedings of the ASME Turbo Expo 2013: Turbine Technical Conference and Exposition. Volume 6A: Turbomachinery, Turbo Expo: Power for Land, Sea, and Air. American Society of Mechanical Engineers, 2013. https://doi.org/10.1115/gt2013-95488. Paper GT2013-95488.

[7] Berhouni I., Bailly D. and Petropoulos I., "Exergy Balance Decomposition Between Mechanically- and Thermally-Recoverable Exergy Outflows", AIAA Journal, Vol. 62, No. 3, 2024, pp. 1232-1239, https://doi.org/10.2514/1.J063118 & https://hal.science/hal-04441331.

[8] Berhouni I., Petropoulos I., Bailly D., "Decomposition of compressible and thermal contributions to the exergy-balance-based analysis of the NASA rotor 37", Paper GT-120925, Proceedings of the ASME Turbo Expo 2024, Turbomachinery Technical Conference and Exposition, GT2024, London, United Kingdom, June 2024, https://doi.org/10.1115/GT2024-120925 & https://hal.science/hal-04653875.

Est-il possible d'envisager un travail en binôme ? Non

Méthodes à mettre en oeuvre :

☒ Recherche théorique	☒ Travail de synthèse
☒ Recherche appliquée	☒ Travail de documentation
☐ Recherche expérimentale	☐ Participation à une réalisation

Possibilité de prolongation en thèse : Oui

Durée du stage : Minimum : 5 mois Maximum : 6 mois

Période souhaitée : From the first trimester 2025

PROFIL DU STAGIAIRE

Connaissances et niveau requis :	Ecoles ou établissements souhaités :
M2, mécanique des fluides compressibles, aérodynamique, thermodynamique, connaissances en codage Python appréciées	Ecoles d'ingénieurs ou Master 2