Dipartimento Meccanica Matematica Management

MUR
Dipartimento
di Eccellenza
2018-2022
2023-2027

Research project

Nome and Surname: Davide Laera

Title: Investigations of stabilization mechanisms and modes transition in Rotating Detonation Engines

Background. Classical gas turbine thermodynamic cycle has undergone no major changes over the last decades and the most important efficiency improvements have been obtained reducing thermal losses and raising the overall pressure ratio and peak temperature. However, current technologies may fall short of complying the increasingly stringent environmental constraints and Pressure Gain Combustion (PGC) emerges as one of the most promising solutions, entailing a pressure rise across the process. In this context, Rotating Detonation Combustors (RDCs) (Figure 1) stands out as disruptive technology for both propulsion and power generation. Indeed, theoretical cycles models show that an increasing of total pressure around 15% - 20% can reduce fuel consumption from 4% - 9% in actual Gas Turbine systems [1]. Moreover, the application of hydrogen could further unlock the numerous potentials of this technology. In order to harness the benefits of RDC and integrate it into gas turbines, a considerable number of challenges arise such as 1) the interaction between shock waves and chemical reactions; 2) the influence of reactants mixing on detonation; 3) the unsteadiness of transonic/supersonic exhaust flow; 4) the appearance of instabilities rising during the off-design operating conditions of these chambers.
Objectives. The overall goal of this action is to augment, by numerical approach, our understanding of the intricate phenomena associated to Rotating Detonation (RD), especially focusing on stable, unstable operating conditions and transitions between different detonation modes [2]. High fidelity numerical simulations represent a valid approach to extend the limits of current experimental setups that miss optical accesses and flow diagnostics when it comes to detonations. First, Direct Numerical Simulations (DNS) on canonical configurations will be used to capture all spatial and temporal scales of the different physics (i.e., fluid dynamic, aerodynamic, turbulence and combustion) interacting in a RDE without relying on any numerical model and associated uncertainties. This first case will be used to quantify the influence of numerical schemes, chemistry modelling, shock capturing techniques, interaction between deflagration-detonation and their numerical resolution [4]. DNS resolution is however unaffordable for numerical simulation of real three-dimensional RDC, especially if several conditions need to be computed to fully characterize the dynamic behavior of RDCs. Therefore, based on DNS results, a Large Eddy Simulations (LES) framework will be developed with the goal of ensuring a balance between high fidelity and computational cost [5-6].

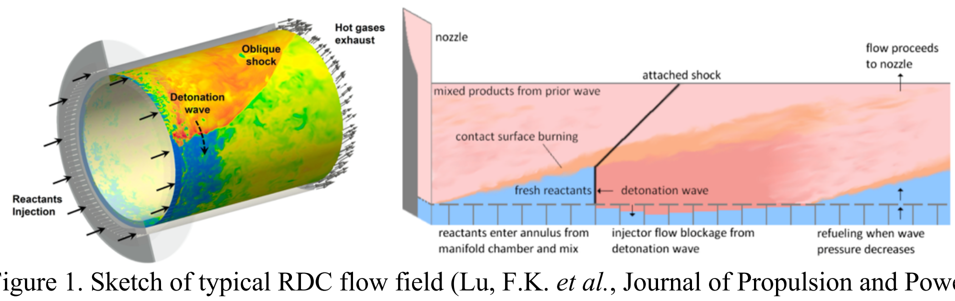

Figure 1. Sketch of typical RDC flow field (Lu, F.K. *et al.*, Journal of Propulsion and Power (2014)).

References:
[1] Jones, S. M., & Paxson, D. E. (2013). Potential benefits to commercial propulsion systems from pressure gain combustion. In 49th AIAA/ASME/SAE/ASEE Joint PropulsionConference (p. 3623).
[2] Xie, Q., Wang, B., Wen, H., & He, W. (2019). Thermoacoustic instabilities in an annular rotating detonation combustor under off-design condition. Journal of Propulsion and Power, 35(1), 141-151.
[3] Bach, E., Stathopoulos, P., Paschereit, C. O., & Bohon, M. D. (2020). Performance analysis of a rotating detonation combustor based on stagnation pressure measurements. Combustion and Flame, 217, 21-36.
[4] Taileb, S., Melguizo-Gavilanes, J., & Chinnayya, A. (2020). Influence of the chemical modeling on the quenching limits of gaseous detonation waves confined by an inert layer. Combustion and Flame, 218, 247-259.
[5] Nassini, P. C., Andreini, A., & Bohon, M. D. (2023). Characterization of refill region and mixing state immediately ahead of a hydrogen-air rotating detonation using LES. Combustion and Flame, 258, 113050.

[6] Strempfl, P., Dounia, O., Laera, D., & Poinsot, T. (2024). Effects of mixing assumptions and models for LES of Hydrogen-fueled Rotating Detonation Engines. International Journal of Hydrogen Energy, 62, 1-16.

Candidates should provide detailed CV

Contacts

Davide Laera: davide.laera@poliba.it