Large Eddy Simulation of flows, flames and acoustic waves in gas turbines and aero-engines

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Abstract

Recent progresses in green-technologies enable today to replace partly fossil fuels with synthetic renewable hydrocarbons. Gas turbines and aero-engines are still, and so will be in years to come, a vital technology for our modern society for converting these fuels into work or electricity. However, gas turbines need to fulfill more and more stringent emission regulations while remaining competitive on the market. Among other avenues, the lean premixed and flameless combustors are of interest in order to achieve low NOx emissions. When reducing the peak temperature, pollutants formation is avoided but stability issues due to the unsteadiness of swirling flames may appear. In order to design new generation technologies, an emphasis should be put on understanding several key phenomena, namely: fuel (gas or liquid) and air turbulent mixing, combustion or flame stabilization and (thermo)acoustic generation. Moreover, deeper understanding of the interaction between these phenomena is also needed.

In this framework, Large Eddy Simulation (LES) is believed a to be a necessary tool to investigate all these issues: it is indispensable for capturing unsteady large scale motions. At present, the complex geometry of the burner implies that handling simultaneously a turbulent flow with a spray and a flame is very costly and requires of high performance computing (HPC) and advanced models. The object oriented structure of OpenFOAM makes it a very promising tool for CFD simulations of gas turbine related flow thanks to the flexibility (adequate models can be implemented and used) and adequacy for massive parallel computing. Our contribution for the workshop will cover our most advanced progresses in the different sub-fields related to gas turbine simulation. In particular, we will present:

- LES of flow in very complex geometry (close to real industrial burner geometry) with high quality/ regularity and fine grids. An example of a flow field is reported in Fig.1. For this typical aero-engine burner geometry, Art Of Illusion was used to import the CAD data and snappyHexMesh was used to generate an unstructured mesh composed mainly of cubic cells.
- Implementation of different LES solvers and combustion models for capturing complex shaped flames using finite rate chemistry including detailed description of the chemical kinetics.
- LES of spray evaporation. For this application, we have also performed a comparisons with our in-house code.
- LES of acoustic noise and active control of the noise. Fig.2 features the exhaust of an aero-engine where jet induced noise is undesirable and in this example is controlled by using fluidic injections/ micro-jets.
- Analysis of turbulent flows and flames using Proper Orthogonal Decomposition (POD). HPC simulation generate a considerable amount of data while only a fraction of the results is of interest for further analysis. We therefore seek to extract only the interesting structures/ dynamics and perform a *data distillation*.

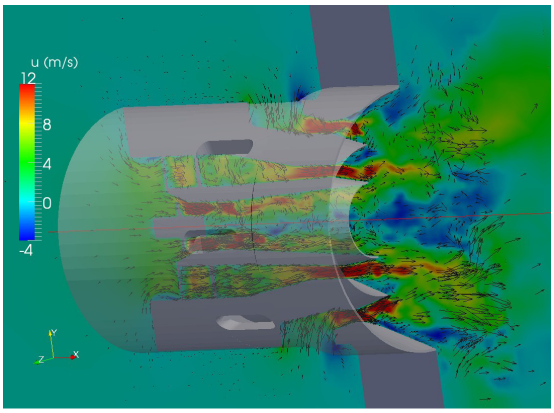

Fig. 1: Axial velocity contour plot and vector map in a longitudinal plane

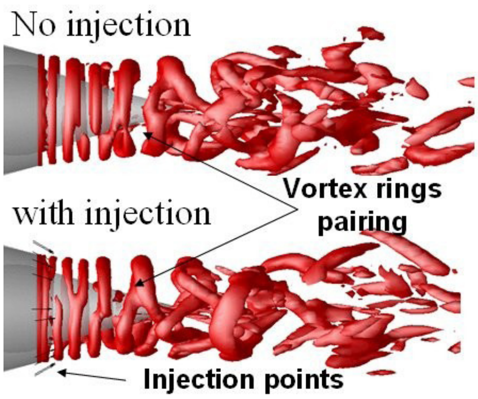

Fig. 2: Vortex rings in a jet exhaust with and without fluidic injection

Key words: Gas Turbines, swirling flows, combustion, flames instabilities, spray, jet noise

The authors suggest that this work is presented in one of the following sessions, in order of significance:

1. Turbulence modelling
2. Combustion
3. Multiphase flow
4. Mesh handling and generation
5. Aeronautics
6. High Performance Computing (HPC)