INTEGRATED LES/URANS SIMULATIONS OF AN AERO-ENGINE GAS TURBINE INTERACTIONS

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Abstract:

The interactions between different component of an aero-engine gas turbine represents a very important aspect of the engine design process. Computatational Fluid Dynamics has commonly been used during both design and analyis process but its use is limited to component simulations which are often designed in isolation. However, the complex unsteady flow features such as, interaction of the unsteady wakes from the compressor blades, hot streaks, cannot be solely accounted for through boundary conditions of single component simulation. Therefore, to shed light on the physics of interactions between the components of a gas turbine (compressor-combustor-turbine) in order to improve their design, there is a need to develop an approach for an integrated simulations of the different components.

The aim of this work is to propose a coupling methodology to simultaneously compute the flow in turbomachinery components and combustor using dedicated solver for each component and exchanging boundary conditions on the fly.

At last year conference [1], we presented results dedicated to steady simulations of the high pressure system of a gas turbine (core of the aero-engine gas turbine) exploiting the interpolation capabilities of CHIMPS [2] developed at Stanford University. This approach is mainly based on transfer of data through file which necessissates a large amount of storage especially in the case of unsteady simulations. In this second part of work which is devoted to URANS/LES/URANS zonal coupling of the high pressure system of a realistic gas turbine a different approach which is based on a more intimate data exchange is chosen. Indeed, in this approach termed "memory based" (to differ it with file based) the data exchange uses message passing interface (MPI). So, the two solvers have been modified such that the data can be directly exchanged through memory, in particular, using the capabilities of the coupler O-Palm [3] and its interpolator CWIPI [4], each code is running in parallel and sharing the same MPI communicator. The principle lays on starting the two programs from the very beginning of the application, exploiting the MPMD mode of

MPI-1. This mode is not part of the MPI-1 standard, but can be found almost everywhere on the various implementations of MPI-1. In this extended MPI-1 mode, many different executables can be launched at the same time, sharing the same MPI communicator.

This approach is used to carry out LES/URANS simulations of a realistic model of an aero-engine gas turbine and compared to standalone simulations of each component. The test case chosen (Fig. 1) encompasses a single sector of a fully featured rich-burn combustor and a single stage of high pressure turbine (HPT). The definition of the boundary conditions requires special attention especially when passing from URANS to LES owing to the different turbulence modelling approach. Since on the LES side part of the turbulent spectrum is resolved a methodology was developed to regenerate and preserve the turbulence at the boundaries. To treat the interface stator/rotor of the HPT, the sliding plane is used.

The Rolls-Royce low-Mach number pressure-based incompressible solver PRECISE-UNS [5] and the density-based compressible solver HYDRA [6] dedicated for combustor and turbomachinery (compressor and turbine), respectively, have been used to carry out this investigation. Both solvers utilize the finite volume discretisation but PRECISE-UNS uses a cell centred formulation while HYDRA makes use of a vertex based median dual control volume.

For LES simulation of the combustor the mesh was carefully designed, using a three stage process, to ensure that there are 12 cells per integral length scale and that more than 80% of the turbulence energy has been resolved and the unresolved subgrid stresses were modelled by Smargorinsky model [7] while the turbulence has been modelled with the k-ω SST for the turbomachinery. Combustion is computed with the Flamelet Generated Manifold (FGM) and liquid fuel is injected using a spray. The numerical results illustrate similarities and differences between coupled and standalone simulations. In fact, coupled simulations show a strong interaction between combustor and turbine which results in impacting the aerodynamic of the flow at the interface combustor/turbine.

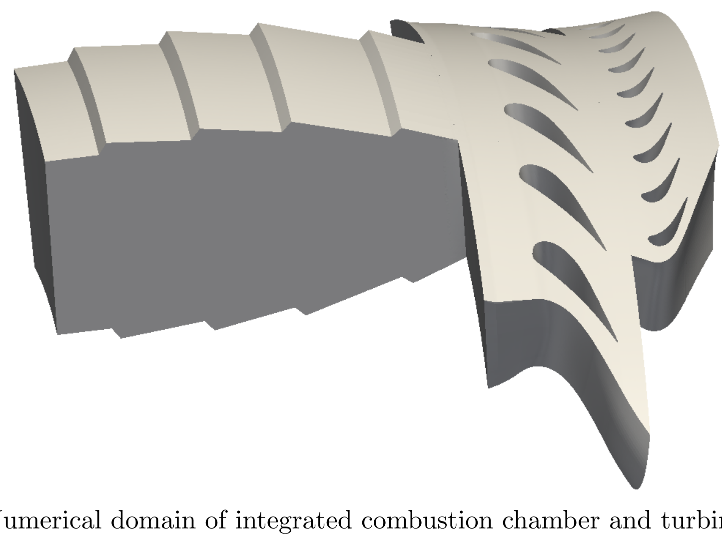

Figure 1: Numerical domain of integrated combustion chamber and turbine simulation.

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