INTEGRATED RANS SIMULATIONS OF COMPRESSOR-COMBUSTOR-TURBINE INTERACTIONS

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Key words: coupled simulation, file based, memory based, interactions compressor-combustor-turbine

Abstract:

During the design process of a gas turbine engine, all key components such as compressor, combustor and turbine are generally designed separately. As the engines are pushed towards higher pressure ratios (resp. high temperature delivery at the combustor/turbine interface) and reduced weight, modern designs are therefore characterized by tight spacing between components, making the identification of their interfaces more difficult and intensifying the interactions between components. Indeed, simultaneously computing all three components (compressor, combustor and turbine) will improve the prediction of the flow through the components and shed light on their interactions.

The aim of this work is to simultaneously compute the flow in turbomachinery components and combustor using dedicated solver for each component and swapping boundary conditions in order to investigate the interactions between the combustor and the turbomachinery components.

For that purpose two ways of coupling have been developed. This first one which exploits the interpolation capabilities of CHIMPS [1] developed at Stanford University is based on file exchange and the second one based on the transfer of data through memory uses OpenPALM library[2].

These two approaches are used to carry out both steady and unsteady RANS simulations of a single spool of a realistic model of a gas turbine engine and compared to standalone simulations of each component. The test case chosen (Fig. 1) consists of six stages of high pressure compressor (HPC), a single sector of a fully featured rich-burn combustor and a single stage of high pressure turbine (HPT). The work is also focused on addressing what constitute a reliable coupling method, given underlying differences of the CFD technology for combustor and turbomachinery simulations.

The Rolls-Royce low-Mach number pressure-based incompressible solver PRECISE-UNS [3] and the density-based compressible solver HYDRA [4] 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. Turbulence has been modelled with the $k$-$\omega$ SST for the turbomachinery and realizable $k$-$\epsilon$ for the combustor. Combustion is computed with the Flamelet Generated Manifold (FGM) and liquid fuel is injected using a spray. The mesh contains approximately 15 million hexahedral cells for the compressor, 25 million elements for the combustor and 6.4 million hexahedral cells for the turbine. The numerical results illustrate similarities and differences between coupled and standalone simulations. In fact, coupled simulations show a strong interaction between compressor and combustor which results in impacting the aerodynamic of the flow at the interface compressor/combustor.

\begin{figure}[h]
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\includegraphics[width=\textwidth]{Figure1.png}
\caption{Numerical domain of integrated compressor, combustion chamber and turbine simulation.}
\end{figure}

\section*{REFERENCES}


