Seminar announcement

DIRECT NUMERICAL SIMULATION OF A BZT DENSE GAS COMPRESSIBLE SHEAR LAYER

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Abstract:

The peculiar thermodynamic properties of dense gases make them of primary interest to the industrial community working on heat recovery and transfer. In the vicinity of the critical point the sound speed drops significantly in dense gases, which leads to a strong increase of compressibility effects. The use of such gases raises modelling issues when numerically designing ORC turbines since the turbulent flows at stake include both significant compressibility effects and potential differences with respect to perfect gases because of the aforementioned uncommon thermodynamic properties - in particular, for BZT gases, the occurrence of an inversion zone in which the fundamental derivative of thermodynamics becomes negative.

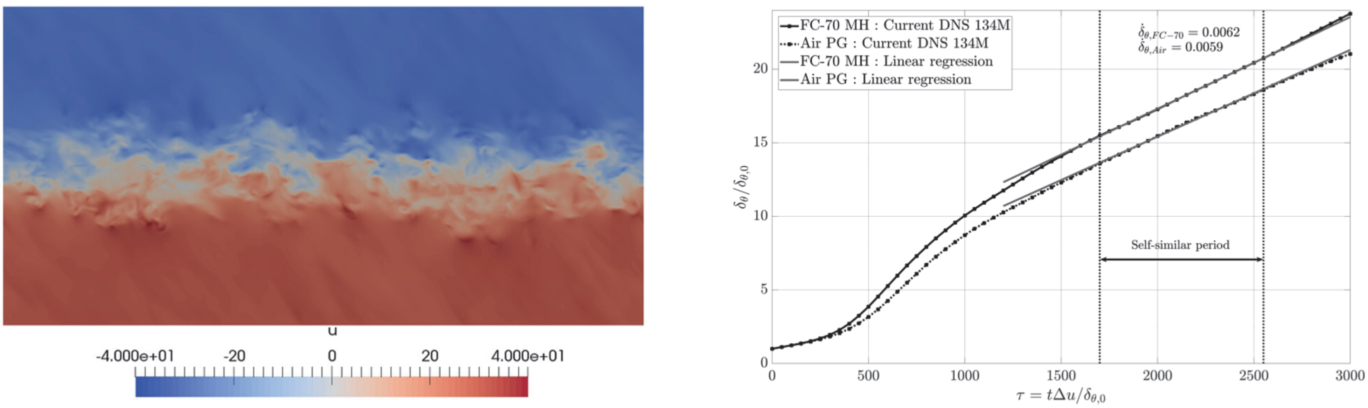

Figure 1. Left: Snapshot of the self-similar streamwise velocity field in the dense gas compressible shear layer at M_C = 1.1. Right: Comparison of the momentum thickness time-evolution for air described with the Perfect Gas EoS and FC-70 described using Martin-Hou EoS.

Direct Numerical Simulation (DNS) is the favored tool to better understand the development of turbulence in BZT dense gas flows and provide both guidelines and validation databases for the subsequent development of subgrid models to be used for Large Eddy Simulation or statistical models to close the RANS equations. DNS of dense gases has been used in few previous works for flow configurations such as freely decaying and forced Homogeneous Isotropic Turbulence and turbulent channel flow. The present study is devoted to the DNS of a time-developing BZT dense gas compressible shear layer. While homogeneous isotropic turbulence may be seen as reflecting the turbulent behaviour in a turbine inter-blade, the shear layer development provides insight into the turbulence characteristics in the blade's wake.

The shear layer under study is produced by two streams of gas flowing in opposite directions (see Figure 1a). The key characteristic non-dimensional number of the flow is the convective Mach number defined as $M_c = (U_1 - U_2)/(c_1 + c_2)$, with U_1, U_2 the respective flow velocity of the lower and upper stream and c_1, c_2 the corresponding sound speed. The DNS of a $M_c = 1.1$ shear layer has been performed for air, described using the Perfect Gas Equation of State and for FC-70, dense gas displaying BZT effects, described with Martin-Hou EoS. Figure 1b displays the computed time- evolution of the shear layer momentum thickness (normalized by its initial value) for air and FC-70. The flow dynamics will be carefully analyzed for both fluids and their respective turbulent kinetic energy balance will be also examined, with a detailed comparions of the production, dissipation, transport, pressure-dilatation and compressible dissipation terms between the perfect and the dense gas. The development of turbulence will be also investigated through spectral analysis of the turbulent kinetic energy balance. This study is expected to shed some light on the specific features possibly displayed by turbulent dense gas flows and motivating a dedicated modelling task.

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