NUMERICAL INVESTIGATION OF DENSE GAS EFFECTS IN TURBINE CASCADES

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The speed of sound in a dense gas flow is related to its molecular complexity. Consequently, the fluid molecular characteristics have a strong effect on the flow field of expansion and compression processes [1]. Existing theoretical studies have already addressed the effects of the fluid molecular characteristics on dense gas transonic and supersonic flow fields. These studies focus on one-dimensional steady flows in simple geometries, such as, for example, the one-dimensional converging-diverging nozzle, which allows for the use of analytical solutions. Simple equations of state were adopted to model fluid properties.

The study detailed in this paper extends the research on this topic to more practical and complex two-dimensional flows such as expansions through turbine cascades and addresses, besides the effect of molecular complexity, the influence of the thermodynamic model employed to estimate the volumetric and caloric properties of the fluid. Expanders operated in the dense gas regime can be found in the power, oil and process industries. The possibility of including complex thermophysical fluid models into CFD codes occurred only lately and consequently the thorough analysis that these simulations allow is a recent achievement.

The thermodynamic models used in this work differ for complexity and therefore accuracy and computational time. The flow field is generated by a standard 2D turbine stator blade profile. Several operating conditions in the dense gas regime are simulated to complete the analysis and to draw conclusions that can be used as guidance in the preliminary design phase.

The fluids chosen for the comparison are: Steam, Toluene and refrigerant R245fa. The fluids are modeled with the polytropic ideal gas law, the PRSV cubic equation of state (EoS), the Martin Hou EoS and the state-of-the-art Span-Wagner EoS [2]. The thermodynamic models and the novel compressible flow solver zFlow [3] are briefly described. All the needed thermodynamic properties, primary and secondary, are efficiently computed from their analytical expressions. Computational efficiency is also addressed.

References

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