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SOME EXPERIENCES ON THE USE OF REAL GAS MODELLING IN HYBRID SOLVER

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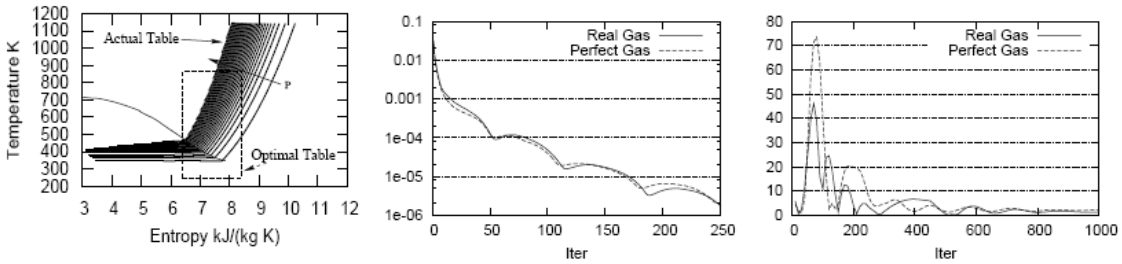
ABSTRACT

The aim of the present work is to report some experiences in the use of real gas modelling for the design/analysis of steam turbines. In fact, the use of CFD in steam turbine investigation has been less widely spread than in the gas turbine mainly because of the lack of a proper modelling for the steam physical properties. The method for implementing a real gas model in a perfect gas RANS flow Solver is reported. The considered solver HybFlow, an in-house CFD code developed by Dr. Adami is based on a 3D upwind unstructured Finite Volume Method with implicit time-marching for steady state flow. The modifications in the discretization scheme, the implementation of the real fluid model and the treatment of boundary conditions will be presented and discussed with the different options approached and the problems encountered.

As the basic code is based on an upwind scheme after Roe's which requires a linear relationship among pressure, density and internal energy, a general approach to real gas requires to move from that scheme to other one more flexible. The new one selected separates the treatment for pressure waves and for the convective fluxes. This separation let the scheme to be more general and insensitive to the specific relationship linking the thermodynamic state variable. The family of AUSM+ (Advection Upstream Splitting Method) scheme possess the necessary blend of robustness and accuracy required to approach real gas. Among many scheme the so call Low Diffusion Flux-Splitting Scheme (LDFSS), after Edwards was selected and revised for the present application assuming a Quasi-1D approximation normal to the faces allowing a straightforward implementation in the existing code.

The method for evaluation of real gas state equation represents a relevant issue for the solver. The possible approaches to this problem may be grouped as direct function representation, parametric general representation or look-up table algorithms (LUT). Benefits and drawbacks for each of them have been analysed and the LUT method has been selected despite the fact that it could introduce some problems in the inverse evaluation at the boundary conditions. Preliminary tests have been carried out with gaseous hydrogen and then it has been applied to steam expansion in a turbine stage. One of the problems encountered in the LUT method is related to the selection of the bounded range ρ-e in the thermodynamic plane since this has consequences on the convergence speed and stability. In the Figure 1 the impact of such problems is reported

for convergence history. The method has been successfully applied to the stage of a low pressure steam turbine. The code has shown satisfactory performance despite of the complex geometry including blade twist, lacing wire and tip leakage (Figure 2). In the investigated stage the effect of the real gas has shown to have a modest impact on the aerodynamic behaviour.



(a) Table in t–s plane (b) Residual Convergence (c) Mass Convergence

Figure 1: LUT, convergence of the residuals and of the mass-flow

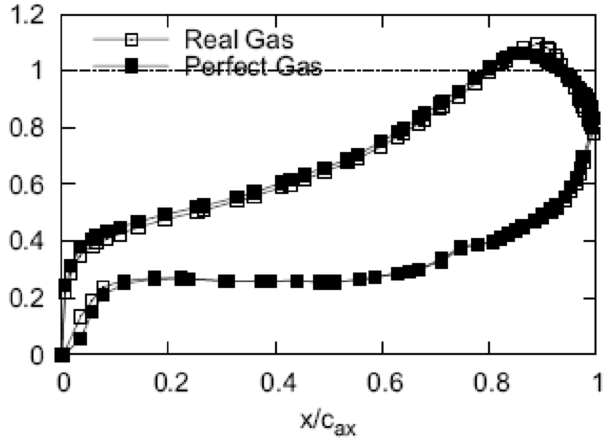


Figure 2 Isentropic Mach number profile

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