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3D SIMULATION OF A RADIAL ORC TURBINE STATOR NOZZLE USING ACCURATE THERMODYNAMIC MODELS

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ABSTRACT

Organic Rankine Cycles (ORCs) are stationary energy converters for external heat sources at low to medium temperature in the small to medium power range. The expansion in ORC turbines partially occurs in the dense-gas region, where the ideal gas law is no longer valid. The fluid dynamic design and performance assessment of ORC turbines therefore requires fluid thermodynamic models that are more accurate than the ideal gas law. The *zFlow* CFD solver [1-4], which is linked to the *FluidProp* library [5] for the accurate evaluation of the fluid thermodynamic and transport properties, has been developed specifically with the aim of simulating these types of flows.

In the *zFlow* code, the spatial discretization of the equations has been obtained by using a finite-element/finite-volume method suitable for general unstructured hybrid grids [6]. A TVD scheme, generalized to the case of fluids governed by arbitrary equations of state following the approach introduced by Vinokur and Montagné [7], has been used to discretize the advective terms. The discretized equations can be advanced in time using explicit and implicit Runge-Kutta time stepping methods. The use of the implicit time integration scheme in steady state computations increases the computational efficiency, especially for fluids characterized by complex models for the calculation of the thermodynamic and transport properties. Recently, the code has been extended in order to solve the three-dimensional Euler equation in cartesian as well as in cylindrical coordinates.

The objective of this work is to demonstrate the capability of *zFlow* to simulate three dimensional flows of ORC turbine expansions. This study therefore considers the stator nozzle of an existing radial ORC turbine which operates with R245fa as working fluid. The flow through the nozzle has been preliminarily studied by solving the inviscid Euler equations in two and three dimensions. This enables a reasonably accurate computation of some performance parameters of interest to the turbine designer, such as the mass flow or the outlet flow angle. The fluid thermodynamic properties are modeled with the state-of-the-art 12-parameter Helmholtz-based equation of state that was recently developed [8,9,10] and the polytropic ideal gas law. Furthermore, a comparison is made between flow field results obtained using *zFlow* and the commercial Fluent solver, which, also since recently, can be coupled to accurate thermodynamic models.

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