Fluid dynamics of supercritical fluids for process and energy applications

Project Aim

The work on optimization of real-gas fluid dynamic designs will be documented in various papers and submitted for publication in at least one journal. Finally, the PhD thesis will be finalized.

Progress

In 2008 the research on various subtopics has resulted in four papers that have been submitted to high-ranking journals. Both the influence of thermodynamic models as well as the influence of fluid molecular complexity on fluid expansions have been investigated using, amongst others, highly accurate thermodynamic models and zFLOW, a state-of-art computational fluid dynamics code. A comparison of computational methods for fluid dynamic design of Organic Rankine Cycle (ORC) turbines, an emerging sustainable energy conversion technology, has led to valuable results and has raised the interest of ORC manufacturers for further ORC technology development. A successful mini-symposium on real-gas fluid dynamics has been organized at the 8th World Congress on Computational Mechanics/5th European Congress on Computational Methods in Applied Sciences and Engineering in Venice in Italy. Results of one of the subtopics of this project has been presented at this conference. In cooperation with the University of Brescia in Italy, an optimization model has been developed for powerful optimizations of real-gas fluid dynamic designs. This model uses optimization techniques based on Genetic Algorithms and Artificial Neural Networks and is coupled to the zFLOW CFD code. The optimization of real-gas fluid dynamic designs allows for new theoretical research into optimal Bethe-Zel'dovich-Thompson (BZT) fluid expansions as well as for applied research into the improvement of the fluid dynamic design of ORC turbines.

Dissertations

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Scientific Publications

1. J. Harinck, A. Guardone, P. Colonna, Influence of Thermodynamic models in 2D Flow Simulations of Turboexpanders, submitted for publication in ASME Journal of Turbomachinery, 2008.
3. T. Turunenen-Saaresti, J. Harinck, P. Colonna, S. Rebay, J.P. van Buijtenen, Computational Study of a High-Expansion Ratio Radial ORC Turbine Stator, submitted for publication in ASME Journal of Engineering for Gas Turbines and Power, 2008.
4. P. Colonna, J. Harinck, S. Rebay, A. Guardone, Real-Gas Effects in Organic Rankine Cycle Turbine Nozzles, AIAA Journal of Propulsion and Power, 24(2), 282-294, 2008.
5. S. Rebay, D. Pasquale, J. Harinck, P. Colonna, A Reynolds-Averaged Navier Stokes Solver Coupled to Accurate Thermodynamic and Transport Property Models, In: Proceedings of the 8th World Congress on Computational Mechanics/5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008), Venice, Italy, July, 2008..
7. P Colonna, A. Ghidoni, J. Harinck, S. Rebay, F. Sussarello, 3D Simulation of a Radial ORC Turbine Stator Nozzle using Accurate Thermodynamic Models, In: Proceedings of the 8th World Congress on Computational Mechanics/5th European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008), Venice, Italy, July, 2008.

Project leaders
P Colonna

Research theme
Complex dynamics of fluids

Participants
J Harinck (PhD Student),
A Guardone (visiting professor),
TP van der Stelt (research associate), Rebay (visiting prof)

Cooperations
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Funded
-

1st - 2nd - 3rd -

Start of the project
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Information

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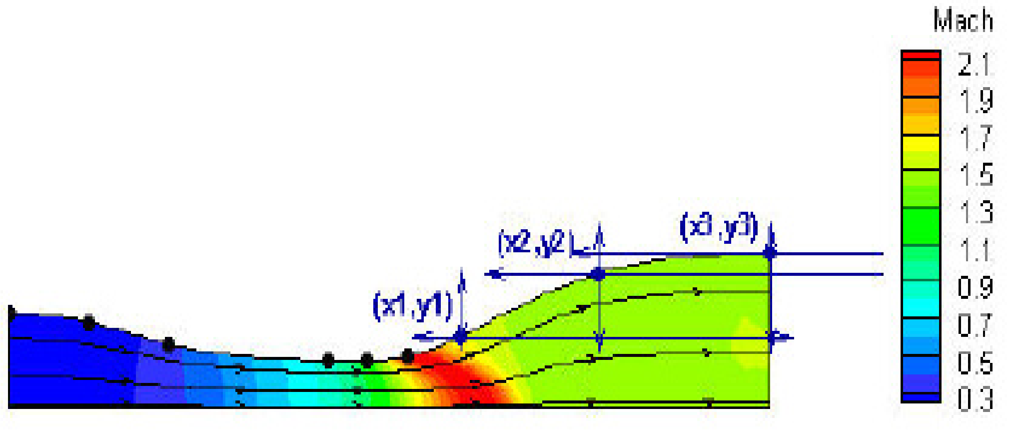
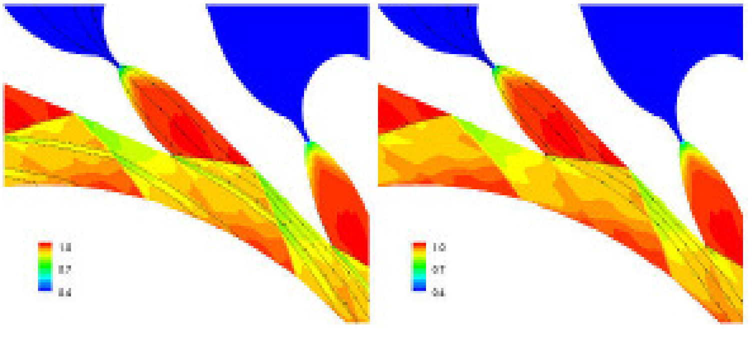


Optimal nozzle shape (no shock waves and uniform outflow) for the expansion of D6, a highly complex (BZT) fluid molecule which allows for the present unusual non-monotone Mach number profile along the expansion. The dots and arrows indicate the shape design variable points that have been optimized within their specified ranges.



Comparison of scaled Mach number fields (with streamlines and total pressure isolines) of the supersonic flow through the stator nozzle of an existing Organic Rankine Cycle turbine as calculated by (a) the inviscid FLUENT and (b) the inviscid zFLOW solvers, respectively. Both flow solvers employ state-of-the-art accurate thermodynamic models to take into account real-gas effects. FLUENT predicts a distinct dissipative wake (which is purely numerical for inviscid simulations) and a stronger oblique shock wave.