

28th Turbomachinery Workshop, October 6th – 8th, 2014
University of West Bohemia, Pilsen

Fast Calculation of Real Fluid Properties for Steam Turbine CFD Analysis with the new IAPWS Standard on the Spline-Based Table Look-Up Method (SBTL)

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Keywords: Spline-Based Table Look-Up Method, thermodynamic properties, numerical consistency, computational speed, computational fluid dynamics

Summary:

For accurate flow simulations with Computational Fluid Dynamics (CFD) extremely fast algorithms for computing real fluid properties are required. In order to meet these requirements, the International Association for the Properties of Water and Steam (IAPWS) issues the “Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL)” as an international standard. Through the use of the SBTL method, spline-based property functions for the independent variables specific volume and specific internal energy (v,u) are generated for steam and water. Thermodynamic and transport properties, thermodynamic derivatives, and backward functions are calculable in the single-phase, two-phase, and metastable regions. Backward functions of the pressure and specific volume (p,v), as well as specific internal energy and specific entropy (u,s) are calculated with complete numerical consistency to the spline functions from (v,u). The properties calculated from these SBTL functions are in agreement with those of the industrial formulation IAPWS IF97 within a maximum relative deviation of 10 to 100 ppm depending on the property and the range of state. Therefore, the differences between the results of process simulations with the SBTL method and those obtained through the use of IAPWS-IF97 are negligible.

Computations from the (v,u) spline functions are more than 200 times faster than the iterative calculations with the industrial formulation IAPWS IF97.

In order to demonstrate the applicability of the Spline-Based Table Look-up Method the developed algorithms have been implemented into the CFD software TRACE of the German Aerospace Center (DLR). As a result, the computing times for flow simulations of steam turbine stages considering real fluid behavior are reduced by a factor of 10 in comparison to the calculations based on IAPWS-IF97. In comparison to CFD-calculations where steam is considered to be an ideal gas, the computing times are increased by a factor of 1,4 only through the use of the SBTL method.

For generating spline functions for fluid property calculations, the software FluidSplines has been developed. This software enables the application of the Spline-Based Table Look-up Method to all kinds of property functions and to other fluids.