

## Fast Calculation of Thermodynamic and Transport Properties in Computational Fluid Dynamics Using the Spline Based Table Look-up Method – STM

Hans-Joachim Kretzschmar<sup>a</sup>, Matthias Kunick<sup>a</sup>, Francesca di Mare<sup>b</sup>, Uwe Gampe<sup>c</sup>

<sup>a</sup> Zittau/Görlitz University of Applied Sciences, Chair of Technical Thermodynamics,  
Theodor-Körner-Allee 16, 02763 Zittau, Germany

<sup>b</sup> German Aerospace Center (DLR), Institute of Propulsion Technology,  
Linder Höhe, 51147 Köln, Germany

<sup>c</sup> Technische Universität Dresden, Chair of Thermal Power Machinery and Plants,  
01062 Dresden, Germany

Email: [hj.kretzschmar@hszg.de](mailto:hj.kretzschmar@hszg.de)

The accurate simulation of non-stationary processes in turbo machinery components with the CFD software TRACE requires precise and extremely fast algorithms for computing thermodynamic and transport properties of the working fluids.

The Spline Based Table Look-up Method (STM) has been developed to fulfill these requirements. With this method, spline functions for the independent variables specific internal energy and specific volume ( $u,v$ ) are generated for water and steam. Using these forward spline functions thermodynamic and transport properties, thermodynamic derivatives, and backward functions of the variables pressure and specific volume ( $p,v$ ), and specific internal energy and specific entropy ( $u,s$ ) are calculated in the single-phase region and in the two-phase region. These backward functions are calculable with complete numerical consistency to the forward spline functions. The properties calculated from STM 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. Consequently, the differences between the results of the process simulation using STM and the results obtained using IAPWS-IF97 are negligible.

The computations from the ( $u,v$ ) spline functions are more than 200 times faster than the iterative calculations using the industrial formulation IAPWS-IF97.

In order to demonstrate the applicability of the Spline Based Table Look-up Method the developed algorithms were implemented into TRACE. As a result, the computing times for flow simulations of steam turbine stages considering real fluid behavior could be reduced by a factor of ten in comparison to the calculation based on IAPWS-IF97. In comparison to CFD-calculations where steam is considered to be an ideal gas, the computing time consumption using STM is increased by a factor of 1,4 only.

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 other fluids.

Projects are being planned to apply the STM besides steam and water to dry air, humid air and combustion gas mixtures in advanced CFD simulations for gas turbines.

The developed method is subject of the “IAPWS Guideline on the Fast Calculation of Steam and Water Properties in Computational Fluid Dynamics Using the Spline-Based Table Look-Up Method (STM)” which is being evaluated and will be adopted as an international standard by the International Association for the Properties of Water and Steam (IAPWS) at its next annual meeting in 2013.