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FAST AND ACCURATE CALCULATION OF THERMODYNAMIC AND TRANSPORT PROPERTIES WITH THE SPLINE-BASED TABLE LOOK-UP METHOD (SBTL)

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The optimization of non-stationary processes in power plants and their components with heat-cycle calculation software, Computational Fluid Dynamics (CFD), and real-time process simulations require accurate and extremely fast algorithms for computing the thermodynamic and transport properties of the applied working fluids.

To fulfil these requirements, the Spline Based Table Look-up Method (SBTL) has been developed in a project from the International Association for the Properties of Water and Steam (IAPWS). This method has been applied to the Industrial Formulation IAPWS-IF97 and the Scientific Formulation IAPWS-95 for the thermodynamic properties of water and steam and the latest IAPWS formulations for the transport properties. SBTL functions of specific volume and specific internal energy (v,u), as well as of pressure and specific enthalpy (p,h) have been generated. With these functions, thermodynamic and transport properties, as well as their derivatives, are calculable in the single-phase region and in the two-phase region. Furthermore, numerically consistent inverse functions of pressure and specific volume (p,v) and specific internal energy and specific entropy (u,s) are obtained from the (v,u) SBTL functions. Analogously, inverse functions of pressure and temperature (p,T), pressure and specific entropy (p,s), and specific enthalpy and specific entropy (h,s) are obtained from the (p,h) SBTL functions. The properties calculated from the SBTL functions are in agreement with those of IAPWS-IF97 or IAPWS-95 within a maximum relative deviation of 10 to 100 ppm depending on the property and the range of state. In the single-phase region, computations from the (v,u) spline functions are between 130 and 470 times faster than those from IAPWS-IF97 and are between 240 and 430 times faster than calculations with IAPWS-95. The (p,h) spline functions are between 3 and 30 times faster than calculations with IAPWS-IF97 and are more than 6000 times faster than calculations with IAPWS-95.

The SBTL method has been successfully applied in several process simulation tools. In KRAWAL, the heat-cycle design software of SIEMENS, the overall computing time is reduced by 50% with regard to calculations based on IAPWS-IF97. In RELAP-7, the leading nuclear reactor system safety analysis software of the Idaho National Laboratory (INL), the simplified property calculation algorithms have been replaced with much more accurate SBTL functions. In the German Aerospace Agency's (DLR) CFD software, TRACE, the computing times for flow simulations of steam turbine stages are reduced by a factor of 10 in comparison to those based on the direct application of IAPWS-IF97. The numerical results of all these process simulations show negligible differences from those obtained through the direct application of the underlying property formulations.

For generating spline functions for fluid property calculations, the software FluidSplines has been developed. This software enables the application of the SBTL method to all kinds of property functions.

The developed method is the subject of the "IAPWS Guideline on the Fast Calculation of Steam and Water Properties with the Spline-Based Table Look-Up Method (SBTL)".