Fast Calculation of Thermodynamic Properties in Process Modelling Using Spline Interpolation

Matthias Kunick [C, S] and Hans-Joachim Kretzschmar
Department of Technical Thermodynamics, Zittau/Goerlitz University of Applied Sciences, Zittau, Germany

Uwe Gampe
Institute for Power Engineering, Technical University of Dresden, Dresden, Germany

Optimizing heat cycles and calculating non-stationary processes both require extremely fast algorithms for thermodynamic properties. For water and steam, the industrial formulation IAPWS-IF97 contains very fast and accurate equations including backward equations for implicit functions which are frequently used in process modelling. In Computational Fluid Dynamics (CFD), however, even IAPWS-IF97 is too slow. For this reason, in CFD fluid properties are often calculated using very simple equations, such as the ideal gas equation. Depending on the range of state, this procedure causes inaccuracies in the process calculation. Table look-up methods are favourable for accurate and fast property calculations. Spline functions can be used in a table look-up method to represent property surfaces continuously. In the first step, bi-quadratic splines for the functions $T(p,h)$, $v(p,h)$ and $s(p,h)$ for steam, region 2 of IAPWS-IF97, were developed. By solving $T(p,h)$ in terms of h, the inverse spline function $h(p,T)$ could be obtained. The computational speed of $T(p,h)$ is twice that of the corresponding IAPWS-IF97 backward equation. The data grid of the spline-polynomials was optimized for the condition that both functions, $T(p,h)$ and $h(p,T)$,represent IAPWS-IF97 with a maximum relative deviation of $1\text{x}10^{-5}$, which is sufficient for process modelling. Moreover the spline functions $T(p,h)$ and $h(p,T)$ are completely numerically consistent with each other, which is important for process calculations. An investigation is in progress to determine spline-interpolation algorithms for thermodynamic properties not only for water and steam but also for other pure fluids and mixtures. Depending on the complexity of the equation of state, computing speed can be increased by factors of 100 or more when using spline functions. The focus of this work is the development of an algorithm enabling efficient generation of spline polynomials and the respective tables for a required range of state and accuracy from a given fundamental equation.