Implementation Of An Optimization Method For Inverse Heat Conduction And Sensor Position Correction

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Abstract

Heat conduction problems can be divided into direct and inverse problems. In direct problems, the thermal boundary condition (heat flux or temperature) is given and its effect is calculated, while for inverse problems the boundary condition is determined based on its effect. For some experimental setups, the measurement of temperature or heat flux at a specific boundary is technically not feasible, because of inaccessibility or thermal loads on the boundary exceed the limit of the sensors, such as thermocouples. Therefore, the thermocouples are placed at favorable locations, which are sensitive to the effects of the boundary and where access is granted. Based on the measured temperature data and the material properties, the heat flux on the unknown boundary can be calculated inversely. However, the inverse calculation is an iterative process and for long runtime experiments with high-frequency optimization, it tends to be inefficient or not applicable.
In this work, the implementation of the inverse heat conduction methods Newton Raphson and Conjugate Gradient Method [1] in LiveLink/COMSOL is introduced. To increase the efficiency and save optimization time, the Jacobian matrix is calculated only at the beginning for the first time step and remains constant during the complete optimization process, as reported in [2]. Further, the thermocouple measurement is a contact-based technique and, depending on the sensitivity of the problem, minor errors in the positioning may have major effect to the inverse calculated heat flux. Hence, the heat flux optimization is extended by a second optimization routine to correct the thermocouple positions iteratively. Both routines are coupled to each other, since the position variation results in a new heat flux optimization. The inverse heat conduction method is applied on the measurements of an in-house test bench. The experimental data are obtained by 10 thermocouples installed within a metal block, which is exposed to reactive near wall flows. The experimental runtime is over two hours. The optimization is realized in Matlab, while the direct problem is solved in COMSOL. The number of optimization points at the unknown boundary is equal to the number of measuring points. The difficulties arise in the positioning and in the exact determination of thermocouple position are corrected by the second position routine. The implemented optimization process combines the advantages of the user-friendly interface of COMSOL to setup a case and the fast Matlab/COMSOL interaction.