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A reduced order model for heated rear window using the method of weighted residuals

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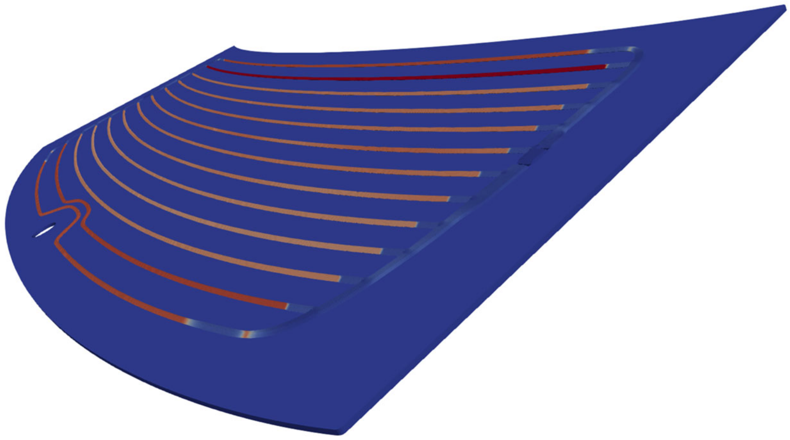

A resistive-heat defroster, also known as defogger, is a standard feature of any car nowadays. The everyday life without a system clearing condensation and frost from the windows or even mirrors is unthinkable. It was developed by Heinz Kunert in the late 60s, but despite the age the design has not changed significantly ever since. A typical defogger consists of thin parallel wires printed onto the window surface or embedded between the layers of a laminated glass. The wires usually consist of a silver-based adhesive and obviously are able to conduct electricity. When a voltage is applied, the electric current flows through the conductors and heats them up. The so-called Joule heating is caused by the non-zero resistance of the wires. Thereby, the resistance is higher for the smaller cross-section of the conductor. Since the conductor lines may be distributed unevenly across the window surface, it is possible that spots are present which emit more heat than the average of the entire system. Avoiding such hot spots and reducing the amount of the costly material are the main optimization potentials.

From the modeling point of view, a simulation of a heated rear window is a non-trivial task. The height and width of the glass is on the order of meters, its thickness is under 1 cm and the conductor layer is only several µm thick. The multiscale problem is relaxed by introduction of the Finite Area Method, which is applied to discretize the equations onto the window surface. First, the electric potential equation is solved for the conductor layer. We use flux reconstruction in order to obtain the correct current even on bad quality meshes. From this, a heat flow due to the Joule heating is calculated and introduced into the heat equation. Thereby, the temperature across the thickness of the wire is assumed to be homogeneous. However, the same assumption cannot be applied to the glass since its heat conductivity is much lower than the one of silver. Here, we incorporate the method of weighted residuals (MWR) in order to depict the cross-wise temperature distribution. Within the MWR, the weighting functions are chosen according to the Galerkin method. This allows the overall solution to be fully conservative.

The MWR is able to reproduce the results from a scale-resolving calculation. In case of the MWR's trial functions being polynomials of 2nd degree or higher, the solution is accurate up to 0.5 K after 20 minutes of the defogger being operated. The evaluation shows that 2nd degree polynomials are sufficient to depict the temperature distribution. In total, the presented model reduces the cost-to-solution several times or even by an order of magnitude compared to a scale resolving Finite Volume calculation.