Automotive Cabin Thermal Comfort Analysis Using a Pseudo-transient Thermal-CFD Coupling Methodology Between TAITherm and OpenFOAM

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Due to the time and cost associated with wind tunnel or field testing, numerical simulation has become a critical step in the automotive cabin design workflow. Considering the wide range of vehicle operating conditions during testing can be especially resource intensive, therefore numerical sensitivity studies can be performed in complement to significantly reduce the development time and cost. However, the thermal conditions of the automotive cabin can be difficult to model due to the transient nature and coupling between the exterior environmental conditions, HVAC system performance, and the heat transfer properties of the vehicle components and passengers. Transient, three-dimensional, coupled thermal-flow simulations are necessary in order to accurately resolve the conductive, convective and radiative heat transfer physics inherent to the vehicle cabin.

In this study, the cabin cooling efficiency of the automotive cabin during operation is analyzed via numerical simulation. A pseudo-transient coupling methodology between the TAITherm thermal solver and the OpenFOAM buoyantsimpleFOAM solver is demonstrated. The coupling was implemented using CoTherm, a CAE automation tool with tight integration to TAITherm. New utilities were written to facilitate data transfer based on standard boundary conditions and function objects available in OpenFOAM. Convective heat transfer in the vehicle cabin was calculated by the CFD solver, while conduction and radiation effects, including solar loading, were calculated in TAITherm. Cabin cooling efficiency was evaluated based on the UC Berkeley comfort model [1]–[6], which predicts the thermal comfort level of an occupant based on local body temperatures and gradients. Additionally, the effects of various design and operating condition changes on thermal comfort were analyzed.

The primary objectives of this study are to demonstrate the thermal-CFD coupling capabilities between TAITherm and OpenFOAM and to illustrate the value of numerical simulation in the automotive cabin design workflow and the transient prediction of thermal comfort.

References:

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