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LOW-FIDELITY MODELLING FOR TRANSPIRATION COOLING BASED THERMAL PROTECTION SYSTEM FOR EARTH RE-ENTRY

Abstract

One of the challenges of human space exploration missions is successfully and comfortably surviving the extreme environmental conditions during atmospheric re-entry. Aerothermodynamic heating is a major hurdle in progressing towards reliable and reusable hypersonic transportation. In the present developmental work, the authors have implemented a preliminary method for modelling transpiration cooling for re-entry vehicles and have explored the possibility to design thermal protection systems (TPS) for Earth re-entry vehicles based on transpiration cooling.

The complexity in analysing the incoming heat flux for re-entry lies not only in the flow being in highly non-equilibrium state on account of very high temperatures but also because of change in flow regime from free molecular to continuum. Additionally, for implementing transpiration cooling, the flow through porous media has to be considered. In the current work a first attempt is made to use the open source computational fluid dynamics (CFD) tool OpenFOAM to analyse the thermal response of a 2D symmetrical re-entry vehicle equipped with a transpiration cooling based thermal protection system.

Using OpenFOAM solvers to treat external high-speed flow and the porous flow, an explicit coupling procedure was developed earlier. The porous region is modelled on a generic local thermal equilibrium (LTE) approach which assumes the local temperature of solid matrix and the fluid to be same. For the preliminary stage in its limited scope, LTE approach is preferred as the microscopic heat transfer coefficients between solid and liquid are not readily available and are difficult to obtain. Independent computations were performed using the coupling procedure for a range of variables to develop a surrogate model using Evolutionary Optimisation techniques. Through this preliminary high-fidelity numerical tool, a low-fidelity modelling approach is derived and presented.