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INVERSE THERMAL ANALYSIS FOR REENTRY VEHICLES

Abstract

The success of either atmospheric re-entry missions or debris management is strongly linked to the computation of the thermal field embedded in the solid shell of the aerospace vehicles involved in such missions. The high level of heat fluxes encountered in such missions has a direct effect on mass balance of the heat shield. Although their assessment is of great industrial interest, such evaluation is mainly possible only in flight conditions by indirect methods based on temperature measurements. For design purposes, it is vital to be able to predict as close as possible the temperature distribution in the solid shell of the vehicle. This theoretical assessment is performed by either simultaneous or sequential solving of the external flow and the internal heat flow equations. The coupling between the two environments is produced through enforcing the heat flux conservation at the interface. The computational effort is quite considerable and there is a plethora of numerical codes performing this type of fluid-structure interaction. Surprisingly, these numerical predictions are not only relatively wide spread against each other but also against the quite scarce amount of experimental measurements, mostly available for laboratory conditions. Real flight measurements are relatively few and dependent on some typical configurations. Our contribution advocates for an inverse analysis of the solid shell thermal field assuming the knowledge, with some degree of uncertainty, of the temperature acquired by a number of sensors located inside the solid body. The method consists of first obtaining a reduced order model (ROM) based on a proper orthogonal decomposition (POD) for the external flow and then applying a Tikhonov regularization and Alifanov's iterative regularization techniques on a similar ROM/POD model for the inverse problem in solid. The paper presents a reconstruction of the external flow conditions around the solid body and the associated reconstructed thermal boundary conditions at the fluid-solid interface at hypersonic/supersonic velocities. The reconstructed results depend on the number of sensors, their locations and the uncertainty measurement.