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STOCHASTIC INFERENCE OF THE CATALYTIC PROPERTIES OF THERMAL PROTECTION MATERIALS FROM PLASMA WIND TUNNEL EXPERIMENTS

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Aerothermodynamics ground testing in high-enthalpy flow facilities is essential for the development and design of aerospace vehicles. It is a convenient step regarding the intensive cost of flight experiments. Moreover, these facilities also have a very practical use to assess the performance of materials, to determine their surface and in-depth properties and to characterize their high-temperature response when exposed to atmospheric entry flows [1]. The determination of catalytic properties of thermal protection materials is subjected to experimental and model uncertainties which must be evaluated during the design phase of reusable atmospheric entry vehicles. In this work, a fully Bayesian approach is proposed combining all set of available measurements to infer the catalytic properties of two different materials, one commonly used for ground testing and the protection material in question.

Sanson et al. [2] showed that the contribution to the measured heat flux of the molecular recombination is negligible and the material catalytic property cannot be estimated with accuracy for the testing conditions considered. This approach presents the conceptual disadvantage of splitting the inference into two stages, one to characterize the free stream upstream the probes and another to infer the catalytic parameter. It further faces the challenge of having to model the dependencies of the free stream flow on the uncertain measurements and possibly also on the catalytic property when it is not exactly known.

The proposed work looks into the conceptual level of the approach to attempt to improve the results obtained for the considered testing conditions with the possibility of extending it to new sets of data [3]. This new approach focuses on the fact that the prior knowledge on both the reference and material probes are incomplete and the two materials should play the same role in the inference process: the measurements should help gaining knowledge on both material properties. The Bayesian inference procedure should therefore not differentiate the treatment of one material from the other, and should be unaffected by our choice of labeling one material to be the reference and the other one to be the thermal protection material. Only differences in the prior distributions of both materials should account for the different levels of knowledge.

The further study of the full set of experimental data can be used to evaluate the effect of the testing conditions on the uncertainty of the catalytic property determination. This will help pave the way to the computation of the optimal testing conditions for the characterization of reusable thermal protection systems, regarded as future work.

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