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Title
Bayesian calibration of a finite-rate nitridation model from molecular beam and plasma wind tunnel experiments

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Abstract
The accurate modeling of gas-surface interaction phenomena is crucial for the prediction of the heat flux and the mass loss experienced by atmospheric entry bodies flying at hypersonic speeds. Gas-surface interactions refer to the set of phenomena occurring between the reactive gas and the material surface, involving heterogeneous chemical reactions together with mass and heat exchange. The surface chemical production rates can be computed using phenomenological or finite-rate chemistry models. In [1] the finite-rate chemistry model derived by Prata et al. [2] was employed to numerically simulate a low-pressure nitridation experimental campaign carried out at the von Karman Institute Plasmatron facility. The model was calibrated both on molecular beam data and on Plasmatron data. The work did not account for experimental as well as parametric uncertainties. In turn, some observed features (e.g., surface recession rates) were not in agreement with the experimental values. This issue underlined the necessity to account for experimental as well as parametric uncertainties during the calibration of the model parameters. In [3], it was shown that Bayesian analyses, which leverage experimental and parametric uncertainties, offer a suitable framework for the calibration of finite-rate surface chemistry models. In this work, we propose to calibrate nitridation surface chemical rates in a Bayesian framework. The calibration is performed by combining wind tunnel and molecular beam data, a first in the ablation literature. The plasma wind tunnel data are explained using a surrogate model that captures the underlying boundary layer in front of the test sample. Such a surrogate model is trained on CFD computations to accurately describe recession rates and CN densities on the stagnation line. The molecular beam data are explained through an analytical model, as in [2]. The parameters' posterior distribution is obtained by constructing a Markov Chain Monte Carlo. Such calibration allows the model to be consistent with both molecular beam and plasma wind tunnel data.

References
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