Uncertainty Quantification and Credible Predictions for Reduced-Fidelity Modeling of Porous Electrospray

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Uncertainty in the parameters of several reduced-fidelity models for porous electrosprays is quantified using Bayesian inference. Particularly, three models employed by the Electrospray Propulsion Engineering Toolkit (ESPET), a reduced-modeling framework for propulsive electrosprays, are examined [1]. 1) The model of Coffman et al. predicting ion current in the pure-ionic emission regime (PIR) [2]. 2) The scaling of Gañan-Calvo et al. for jet current in the cone-jet emission regime [3]. 3) The empirical model of St. Peter et al. for the number of active emission sites as a function of applied voltage [1]. Parameters are learned using experimental data available in the literature, yielding posterior distributions over parameter space (see Fig. 1). Inferred model parameters are compared within deterministic values previously reported and agree within an order of magnitude. Probabilistic performance predictions with credible intervals for a real electrospray emitter are then made using the inferred parameters and the ESPET QuickSolver. These predictions are found to underestimate the experimentally measured current of the emitter by about a factor of 3 across the domain, and the pure-ionic emission scaling is discussed as a cause. The inference is updated by incorporating the "new" experimental data. It is found that the ionic current scaling parameter changes much more significantly than the other parameters, supporting it as the primary source of disagreement. Additional predictions are then made excluding the original PIR data (see Fig. 2). Potential lack of applicability between different propellants and the role of model parameters (e.g. emitter geometry) that were taken as certain for this analysis (but may in fact be significantly uncertain) are discussed. The methodologies employed are examined within the context of a novel development strategy for electrospray thrusters that combines the ESPET reduced-fidelity modeling framework and rapid prototyping in a robust design optimization loop.

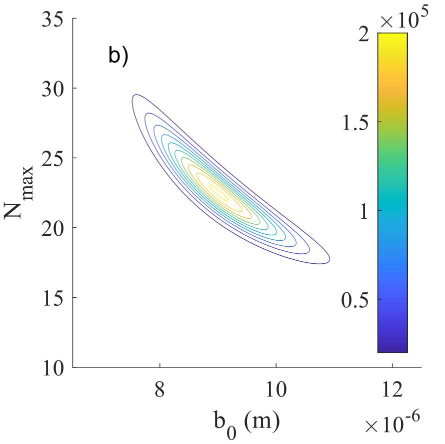

Figure 1 – Joint posterior distribution of parameters b_0 and N_{max} of the empirical model for number of emission sites as a function of voltage [1,4].

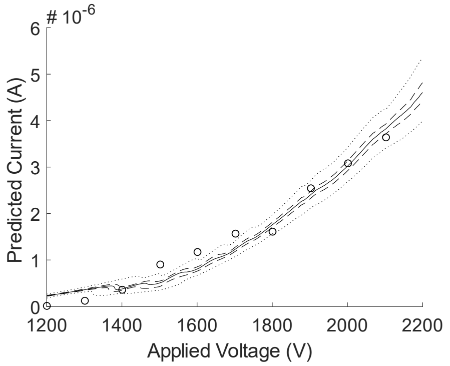

Figure 2 – Probabilistic performance predictions for emitter current as a function of applied voltage with credible intervals (solid: median, dashed, 33rd and 66th percentile, dotted: 2.5th and 97.5th percentile), compared with experimental data (circles) [1,4].

References

[1] B. St. Peter et al., Aerospace. **7**, 91 (2020).
[2] C. Coffman et al., Appl. Phys. Lett. **109**, 23 (2016).
[3] Gañan-Calvo et al., J. Aer. Sci. **125** (2018).
[4] C. Whittaker et al., AIAA P&E 2020 Forum (2020).