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Parameter estimation and uncertainty quantification for shock-wave simulations with a Bayesian inference approach

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We consider the class of impact-induced shock-wave problems where the model parameters are under large uncertainties as a result of huge variations of the physical states as well as a limited amount of data available. The forward model is based on an Euler equation set (the MESA code) and the data is from the pressure measurement of flyer-plate experiments. The current study employs the Bayesian formulation for the inference of the model parameters based on ensemble simulation runs and single-point pressure data at various temporal points. The statistical model relies on the Gaussian process using the Markov chain Monte Carlo sampling technique for the constructions of the statistical response surface and the posterior distributions. The study aims to address the following aspects: (1) uncertainty of the overall shocked system based on our experiment design, (2) uncertainty of the model parameters and the data, (3) sensitivity analysis of the system to the parameters, and (4) discrepancy between the simulation code and the true system and how it is handled in the inference.

This study is also considered as an extension from our earlier work using the same code and data with the extended Kalman filter method (Kao et al., 2004, 2005) in which information is entirely deterministically obtained through the maximum likelihood inside of the Bayesian framework. The quantitative comparisons between the two approaches will be of interest in the current work. The ingredients used in this study also provide us opportunities to investigate the emerging sequential particle filtering technique where each ensemble member carries a different weight in constructing the posterior distributions. The information arising from the interplay among all of these approaches is useful for future studies of uncertainty quantifications and predictability of dynamic systems involving shock production and propagation. (U)(ADC=jk)

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