Abstract

Inverse problems find their applications in engineering of various thermo-fluid systems. Finding a solution to inverse problems has been challenging due to their ill-posed nature. A solution to inverse problems is a promising area of research that could help find various unknown model parameters that are otherwise difficult to obtain. In the past few decades, various deterministic and stochastic methods have been developed to find a solution to inverse problems. The present work aims to develop a computational framework using Bayesian inference, which leads to forward propagation of uncertainty in various thermo-fluid model problems and solves the corresponding inverse problems.

To solve inverse problems in various thermo-fluid systems, a computational framework has been developed using Bayesian inference. The framework leverages the polynomial chaos expansions (PCEs) to generate computationally efficient and statistically equivalent surrogate model of the computationally expensive forward model. The applicability of the framework is established by validating different model problems in thermo-fluid systems.

At first, the developed framework is used to find various non-dimensional parameters in a heat and mass transfer problem in porous media. We solved an inverse problem in a coupled heat and mass transfer system to estimate model parameters in a one-dimensional capillary porous media using Luikov's model. These solutions help to obtain various thermophysical properties of the porous medium.

Next, we demonstrate the application of the framework to a heat conduction model. We describe the accelerated Bayesian inference framework to solve inverse heat conduction problems to estimate boundary heat flux. Along with the polynomial chaos expansions to provide a computationally efficient and statistically equivalent surrogate model for the computationally expensive forward model, this model problem also includes di-

mensionality reduction using the Karhunen-Loeve (K-L) expansion. We demonstrate the potential of this approach using two model problems to estimate heat flux in inverse heat conduction models. We represent the heat flux using K-L expansion to reduce the high dimensionality of the heat flux and compute the posterior probability distribution of the heat flux using the temperature measurements. The first inverse problem involves the estimation of time-varying heat flux in a one-dimensional slab using transient temperature measurements. The second problem consists of estimating the unknown transient heat flux of the disc in a realistic disc brake system.

Lastly, we have demonstrated the application of the framework on large-scale petroleum reservoir models. We estimated the various geological properties of a petroleum reservoir which helps in optimising reservoir performance and risk analysis. We studied the effect of uncertain geological parameters such as porosity and permeability on simulation outputs, such as oil production rate and gas production rate, using the Bayesian inference-based non-intrusive polynomial chaos method. Our simulations yield the mean and standard deviation of production forecasts and also determine the relative contribution of uncertainty in input parameters on the predictions. We performed simulations of petroleum reservoirs, considering the heterogeneity of the reservoir. We used the developed stochastic technique based on PC expansions to propagate uncertainty from model parameters to model predictions. The developed framework can also be used along with commercial simulators of petroleum reservoirs.