Numerical models and uncertainty quantification applied to innovative energy systems

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When performing numerical simulations for energetic systems, uncertainty quantification is a powerful tool to assess numerically their physical behavior. In these applications, some physical parameters are often pretty difficult to estimate, due to a lack of direct and robust measurements. Also, for simulation feasibility and cost, some modeling approaches force us to make assumptions to represent the physical processes. The predictive character of the models is then reduced if we consider these latter uncertainties, known as model and parametric uncertainties. Quantifying the uncertainties inherent to the models, using statistics and probability methodology, allow to produce robust numerical predictions. In this talk we present how to apply this methodology and their outcomes on two examples: (1) a Lithium-ion battery thermal management system and (2) a liquid piston compressor dedicated to hydrogen applications:

(1) Battery Thermal Management Systems (BTMS) feature numerous Li-ion cells stacked in an enclosure, where a liquid circulates to dissipate the heat produced by Joule effect during the batteries operation. Representing the phenomenon, from the electrochemical scale up to the heat transfer at pack level requires to build complex multi physics and multi scale models. A Bayesian calibration allows to reduce the uncertainties on the internal resistance of the batteries and to construct a robust model for this parameter. Then the predictive power the dedicated CFD solver is considerably increased, by featuring narrow ranges of probable model responses [1, 2].

(2) On liquid piston compressor, an experiment was set up at LIFSE laboratory in order to study the efficiency of the system. Many uncertainties, coming from the experimental facility and physical parameters, make the assessment of the compression cost inconclusive. Then, using experimental data and a numerical model, a uncertainty analysis, featuring Bayesian calibration and propagation of uncertainties allowed to assess the performances of the system.

References

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[2] E. SOLAI, et al, Validation of a data-driven fast numerical model to simulate the immersion cooling of a lithium-ion battery pack, *Energy*, **249**, 123633 (2022), `https://doi.org/10.1016/j.energy.2022.123633`