Robust Experiment Design for Identification of Thermophysical Parameters – Part I: Acceleration Using Polynomial Chaos Expansion and Sobol Indicies

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Abstract

Laboratory experiments are still mostly designed by trial and error method using the expert knowledge of the material model to be calibrated. This is, however, a difficult task in the case of advanced models developed to simulate engineering problems by non-linear finite element techniques. Ruffio et al. (2012) proposed method for optimisation of model-based design of experiments using robust evolutionary algorithms. Such a method, however suffers from the high computational demands, which make their application to non-linear finite element (FE) simulations difficult. In this contribution we present a novel method introducing surrogate of FE model based on polynomial chaos expansion (PCE) and global formulation of sensitivity matrices. PCE- based surrogates bring two principal advantages. First, they allow to overcome the computational burden of many times repeated FE simulations within the process of experiment design optimisation. Second, they allow fast analytical evaluation of Sobols indices or response variances, which can be used for quantification of global sensitivity of measured quantities to identified parameters, see Blatman and Saury (2010). The advantages and drawbacks of the proposed method are demonstrated on an experiment designed for identification of the volumetric thermal capacity and the conductivities in the two principal directions. The specimen is modelled by 2D squared domain with the prescribed constant heat flux on left and bottom edges and the goal of the given experiment design is to find optimal positions of three sensors. It is demonstrated that PCE-based formulation of global sensitivity matrix allow for (i) a design of experiment being robust w.r.t. large feasible intervals for identified material properties as well as uncertainty and noise in experiment design parameters (e.g. value of a loading level or sensor positioning) and (ii) design process being computational feasible for large nonlinear systems.

References

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