Variational Bayesian inference of a gradient-enhanced damage material model

Abbas Jafari*, Thomas Titscher*, Tyler S. Oesch*, Eleni Chatzi† and Jörg F. Unger*

* Division of Modelling and Simulation
Federal Institute for Materials Research and Testing (BAM)
Berlin, Germany
{abbas.jafari, thomas.titscher, tyler.oesch, joerg.unger}@bam.de

† Institute of Structural Engineering (IBK)
Swiss Federal Institute of Technology (ETH)
Zurich, Switzerland
chatzi@ibk.baug.ethz.ch

Key Words: stochastic inference, material model updating, variational Bayesian, gradient-enhanced damage

ABSTRACT

Updating numerical models of structures in accordance with experimental data is an essential prerequisite for utilizing those models for the reliability assessment of the structures. This often requires the identification of important material parameters, to which the model’s behavior is more sensitive. To achieve a more realistic model, one also needs to take into account various uncertainties; e.g. in the experiment, in the model itself, and in measurements. Towards this purpose, stochastic methods infer quantities of interest in the form of probability distributions instead of deterministic values.

A finite element (FE) model is calibrated with respect to important parameters of the respective constitutive law, which is the gradient-enhanced damage material model originally proposed in [1]. Raw computer tomography data - in the form of 2D images slicing the whole domain of the specimen over the course of experiment - is converted to displacements using the method of digital volume correlation. This provides informative data for constructing an appropriate objective function to be minimized in the inference problem. The objective function is similar to the one defined in the “equilibrium gap method” [2], which includes the residual vector of the FE model (the gap between external and internal forces) and is further contributed by a penalty term: the gap between measured displacements and an arbitrary set of admissible displacements. The latter should fulfill homogeneous Dirichlet boundary conditions (of the experiment) and is imposed to the model as Dirichlet boundary conditions. The unknown quantities; i.e. material parameters and admissible displacements, are then considered as random variables and estimated in the form of normal probability distributions using the variational Bayesian technique proposed in [3].

One challenge in solving the optimization problem described above is the need for numerous iterative computations of the so-called jacobian: the derivative of the objective function with respect to the inference parameters. Typically, one computes the jacobian numerically. Nevertheless, this is computationally too expensive for the present nonlinear problem with too many inference parameters including all degrees of freedom of the admissible displacements. In this work, an analytical scheme is developed to compute the jacobian more efficiently.
REFERENCES

