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Modeling of a Damage Detection Problem in a Structure Subject to Uncertainties Using Multi-Objective Stochastic Optimization Techniques

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Summary

In this work, the inverse problem of identifying the presence and location of holes in a plate structure, with parameters described as random variables, is modeled using multi-objective stochastic optimization techniques. The direct problem of obtaining the distribution of stresses in a plate containing a damage can be modeled through the boundary element method for elastostatics. The damage can be characterized by changes in the structure, such as the presence of holes and/or cracks. Identifying and locating the damage is an inverse problem, which can be solved using optimization procedures. For that, several numerical models can be created simulating the damage at different locations, and the values of the quantities of interest, say, the stresses at pre-defined locations, can be obtained numerically. By comparing the various sets of numerical stresses with the values of the measured stresses at the same locations, for a real damaged structure, a functional can be created from the differences between the numerical and the real stresses. The minimization of this functional will lead to the identification of the damage parameters, such as its type, size and location. One must note that several values of the measured and the numerical stresses, which are components of the stress tensors, are obtained at the interior points of interest, to be compared. In order to avoid discrepancies when comparing stresses obtained in different planes and directions at a particular point, the stress information is reduced to independent scalar quantities at this point, namely, the invariants of the stress tensor. Several parameters of the model, such as its geometry, material properties, boundary conditions, size and location of the damages, etc, are subject to uncertainties in a real structure. To account for the uncertainty in the model parameters, a stochastic treatment is done for the related random variables. Based on the uncertainties in the input variables, the uncertainties in the response variables can be assessed through response surfaces techniques. In this case, several response surfaces can be obtained, for the objective functions and also for the constraint equations in the optimization model. In order to obtain the response surfaces, a design of experiments approach is used, to consider the influence of each factor in the results obtained. A complete factorial experiment technique is used, wherein for each factor three levels are simulated: mean level, upper level (mean plus three standard deviations), and

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lower level (mean plus three standard deviations). When analyzing the results of the experiments, the focus is to identity the effect produced in the response when the levels of the input factors are made to vary. For this two-dimensional problem, the mean stress and the octahedral stress are chosen as stress invariants, and the summation of the differences squared of these quantities for all interior point locations leads to two independent functionals to be minimized. These response functionals are meta-models of the distribution of stresses at the interior locations, obtained through the response surface methodology by varying the various input variables, such as the damage parameters. The problem of minimization of these two objective functions is handled using multi-objective optimization techniques, to identify and locate the real damage in the structure.

keywords: Damage detection; Uncertainties; Response Surface Methodology; Multi-objective optimization; Stochastic optimization