Structural damage identification with incomplete modal data using the differential evolution algorithm

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ABSTRACT

Structural damage identification has drawn increasing academic interest, as witnessed by the number of relevant journal and conference papers, during the recent years. The necessity of detecting and repairing structural damage at its early stage has become imperative and considerable effort has been devoted to developing non-destructive testing and evaluation (NDT&E) techniques. Among the NDT&E techniques that have received significant attention in the computational mechanics field are those based on vibration analysis in order to obtain global information about the condition or state of health of the structural models using measured dynamic data. Such techniques use vibration characteristics of the structures including frequency response functions, natural frequencies, mode shapes, mode shape curvatures, modal flexibilities, modal strain energy, etc. to identify occurrence of structural damage.

There have been many studies intending to find a reliable method to identify damage in structural elements both in location and extent. Most damage identification methods based on the changes of dynamic characteristics encounter problems in the identification of damage when incomplete experimental data are taken into account. A class of damage identification methods is based on the modification of structural model properties such as mass, stiffness, and damping to reproduce as closely as possible the measured static and dynamic response obtained from the experimental data. These methods update the physical parameters of the finite element model of a structure by minimizing an objective function expressing the difference between finite element predicted and experimentally identified structural dynamic properties that are sensitive to damage, such as natural frequencies and natural shapes.

In this study, a structural damage identification method based on the finite element model updating is proposed, in order to provide the location and the extent of structural damage. The problem of damage identification is treated as a single-objective optimization problem (without constraints) and the modal correlation parameters are used to formulate an objective function. The data that are used to calculate the objective function are acquired by the modal analysis of the damaged structure (simulated experimental data), applying the finite element method and the differential evolution algorithm is employed to detect damage in structural elements by minizing the objective function. The performance and robustness of the proposed approach are evaluated in a test example of a simply supported beam, with several damage scenarios. It is shown that the obtained results confirm the high efficiency of the proposed approach for accurately identifying the location and extent of structural damage.

References

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