8th. World Congress on Computational Mechanics (WCCM8)
5th. European Congress on Computational Methods in Applied Sciences and Engineering (ECCOMAS 2008)
June 30 – July 5, 2008
Venice, Italy

Damage Identification for Bridges Based on Multi-type Sensors

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Key Words: *Damage Identification, Multi-type sensors, Sensor Placement, Structural Health Monitoring.*

ABSTRACT

Damage identification is a very important part in Structural Health Monitoring Systems [1]. The success of damage identification is mainly dependent on three factors: the model, the measurement and the damage parameter identification algorithm.

For bridge structures interested in this paper, supposing geometric properties do not change when damages present, the effective Young's modulus can indicate the change of structural stiffness. Therefore, a bridge is subdivided into several segments with independent Young's moduli. Static deformations and strains are the natural choices of measurements due to their high sensitivities [2-4]. As a mathematical programming problem, the success of damage identification is mainly dependent on the selection of a proper objective and a nonlinear optimization algorithm. The simple objective of least-squares estimation is adopted in this paper, because it does not require any *a priori* information and hence avoids specifying any empirical parameters. Corresponding to this objective, Gauss-Newton method is a good optimization algorithm.

The procedure of parameter identification is ill-posed in nature and practical measurements are inevitably contaminated by noises. To ensure the well-posedness of this procedure, one can use the optimal measurement layout [5-9] or account for certain kind of regularization method [9, 10]. This paper uses the first method.

The design of the optimal measurement layout is a combinatorial optimization problem [5-9], associated with a criterion of optimality. Most popular criteria are more or less related with certain properties of Fisher information matrix [7]. Based on these criteria, simple heuristics [5, 6, 9] as well as modern meta-heuristics [8, 11] have been adopted to find the optimal solution. So far, most researches discuss only the optimal layout of mono-type sensors. But a network of heterogeneous sensors is commonly used to measure different kinds of variables, such as deflections, rotation angles and strains in real bridge testing. Therefore, it is natural to identify damage parameters from these measurements, and is important to study the optimal sensor placement under this circumstance.

Based on the analysis of well-posedness of parameter identification procedure, this paper develops a new criterion of the optimal sensor placement when multiple types of sensors are involved. A new heuristic based on local search techniques is proposed to

solve the combinatorial problem efficiently. Moreover, to remove the side effect of specifying initial parameters empirically, sensor placement design and parameter identification are conducted alternatively [12]. Furthermore, for the scenario of multiple loading cases, Monte Carlo simulation is carried out in advance to obtain a super set of candidate measurements. Thus, the redundancy of measurements is naturally considered and the robustness of damage identification is ensured. Finally, the validity of these methods is illustrated by some numerical examples.

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