Application of R2PSO Algorithm in Crack Detection of Functionally Graded Beams

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A fault diagnosis procedure based on r2PSO algorithm—a newly developed version of particle swarm optimization (PSO)—is presented for detecting crack depth and location in a functionally graded material (FGM) cantilever beam. The governing equation and boundary conditions are obtained by using the extended Hamilton’s principle, and the characteristic equation is obtained as a function of position ratio and depth ratio of crack. Identification of the crack is formulated as an optimization problem. The r2PSO algorithm is used to find the optimal solution of the cost function, which is based on the summation of the absolute value of the characteristic equation for three natural frequencies. The position ratio and depth ratio of crack are computed by algorithm, when three natural frequencies of FGM beam are entered to algorithm as inputs. The obtained results confirm the applicability and efficiency of r2PSO to calculate the parameters of crack with high accuracy and suitable convergence rate.

1. INTRODUCTION

The existence of a crack in a structural member would change the dynamic behavior of the structure. Changes in overall dynamic of structure present serious threats to performance of the structures such as structure failure. Therefore, many researchers have proposed the different methods to detect and localize the crack in the structures.1-7 One of the inhomogeneous composite structures is FGM, which have great applications in aerospace vehicles, nuclear reactors, power generators and automobile structures. A crack has occurred in FGM structures and numerous researchers have investigated the fracture analysis of these materials.3-7

The location and size of an open edge crack has been determined in an FGM beam by Yu and Chu.8 They utilized the p-version finite-element method to estimate the transverse vibration of an FGM beam. The influences of crack size, crack location and material gradients have been studied on the natural frequencies of the FGM beam. Numerical experiments have demonstrated the efficiency of their proposed method.

Wei et al.9 studied free vibration of cracked FGM beams with axial loading, rotary inertia and shear deformation. The model of the crack was the rotational spring model. The influences of the location and total number of cracks, material properties, axial load, inertia and end supports on the natural frequencies of FGM beams have also been studied. Xiang et al. have developed a combination of wavelet-based element and genetic algorithm to detect the location and depth of the crack in a rotating Euler-Bernoulli and Timoshenko beam.10 Some numerical and experimental results have indicated the performance of their method.

Vakil Baghmishe et al. have proposed the crack identification of a beam as an optimization problem.11 The cost function of problem was based on the difference of measured and calculated natural frequencies. The binary and continuous genetic algorithms were used to find the optimal location and depth of crack. In order to validate the modeling and method, the results have been presented by some experimental results. An improved particle swarm optimization was developed to detect the damage of structures.12 The algorithm was a combination of the particle swarm optimization and the artificial immune system. Results have shown the feasibility and efficiency of that improved algorithm.

Nonlinear vibration of the cracked FGM beams has been studied by Kitipornchai and et al.13 A direct iterative method has been used to find natural frequencies and mode shapes of beam. The effects of crack location, crack depth, slenderness ratio, material property, and boundary conditions were shown on the nonlinear vibration characteristics of the FGM beam.

Fernando and et al.14 indicated the crack detection in structural elements by means of a genetic algorithm optimization. The methodology has been applied to beam-like structures and any other arbitrary shaped 3-D element. The input data in algorithm has been obtained with a cantilever damaged beam in physical experiments. Birman and Byrd15 examined free and forced vibration of damaged FGM beam. They modeled the damage to region with degraded stiffness adjacent to the root of the beam, a single delamination crack and a single crack at