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Crack detection by means of static and dynamic simulations with a crack contact model

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ABSTRACT

Most of the methods to detect a crack in beam-like structures are based on linear one-dimensional models. Evidently these approaches are not straightforwardly applicable to structures such as beams or arcs with an open crack or a breathing crack without or with contact. The present study deals with bi and tri-dimensional models to handle the statics or dynamics of an structural element (with an arbitrary shape) with a transverse breathing crack. The crack is simulated as a notch or a wedge with a unilateral *Signorini*'s contact model. The contact may be partial or total. All the simulations are carried out using the general purpose finite element code FlexPDE. Figure 1 depicts the deformed beam after being freed with initial conditions and shows the contact between the crack interfaces.

A genetic algorithm (GA) optimization method is successfully employed for the crack detection. The response at some points of the damaged structures are compared with the solution of the computational (FE) model using least squares for each proposed crack depth and location. An objective function arises which is then optimized to obtain an estimate of both parameters. It was found that the functions present a large number of local minima. Given such a complexity, the standard optimization techniques (e.g. gradient methods) are not successful when used directly. Then the genetic algorithm is employed as an initial stage to find a seed to input in the gradient optimization algorithms, in what follows named *hybrid tool* (HT). Several results of crack detection have been found for beam-like structures, though other structural elements can be handled. At present crack detections in an arc and a blade-like structural element are under study. Table 1 depicts one of the studied dynamic cases and the resulting estimates using the hybrid tool. The beam is clamped, 2.5 m long, with a cross-section 0.25 m x 0.1 m and material characteristics: Young's modulus $E = 7.3\ 10^{10}$ Pa, mass density $\rho = 2766$ kg/m^3 and Poisson's coefficient $\nu = 0.3$. Six different scenarios have been studied in this example.

Extensive studies were carried out to analyze the influence of the various parameters involved in the GA. The parametric studies permited to set the following optimal values for this problem: population (50), reproduction (heuristic crossover with ratio of 0.6), number of generations (5). Both lineal and non-linear models were considered for the beam material. Here the first one is employed since the initial

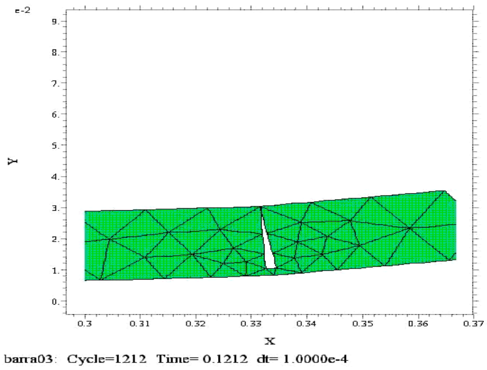

Figure 1: Instant deformation of a damaged beam with partial contact at the breathing crack interfaces.

Table 1: Crack detection in a beam using the hybrid tool (HT) and a finite element model. Example.

Scenario	1	2	3	4	5	6
Crack location (from left end) (m)	0.1	1	0.1	1	2	1.5
HT detection	0.095	0.996	0.0851	0.998	2.04	1.497
Crack depth (cm)	10	10	20	20	5	2
HT detection	10.2	9.53	21.55	19.59	5.09	2.06

conditions given to the structural element in order to start the motion yield small deformations. The results were confirmed with the non-linear model. However the computational times are, as expected, smaller with the linear approach. A general isotropic linear constitutive relationship between the second Piola-Kirchhoff stress tensor and the Green-St. Venant strain tensor was proposed for the non-linear case. Aditionally a white noise was introduced and it was found that the errors remains in the same range. The methodology allows up to a third level detection, i.e. detection of damage existence, location and depth. The errors are reasonable given the nonlinearities introduced by the contact problem and the inherent complexity of the inverse problem.

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