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An Analytical Method for Crack Detection of Beams with Uncertain Boundary Conditions by a Concentrated Test Mass

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Abstract

The aim of this study is to introduce a method for crack detection and simultaneously assessing boundary conditions in beams. This study suggests a method based on the effect of a concentrated test mass on the natural frequency that is defined as a stationary mass, which can be located in different positions of the beam and cannot be separated from the beam. Timoshenko beam theory is used to calculate the frequencies. In this method, a beam with the desired number of cracks is modeled. The beam is divided into separated parts at crack section, which are joined together by elastic weightless torsion springs, to avoid non-linearity effects; it is assumed that the crack is always open. At the first step, equations for a cracked beam are extracted by considering the spring boundary conditions. Then, to verify the equations, numerical finite element model is used. In this way, a new method is also applied to model the torsion springs in supports and it is shown that suggested model is acceptable. Eventually, the obtained responses are evaluated and the sources of errors are identified. To correct the existing errors, a modifying function is suggested. Finally, the inverse problem is solved.

Keywords: Timoshenko Beam Theory; Test Mass; Dynamic Characteristics; Cracked Beam; Spring Boundary Conditions.

1. Introduction

Generally, to ensure lifetime safety of structures, their health should be monitored continuously to enable possible damages detection. Therefore, many studies have been conducted in damage detection so far [1]. Non-destructive testing methods are common in crack detection, but these methods are much expensive in comparison with computational methods. On the other hand, in computational methods (e.g., frequency based methods), experimental data collection from one point may be sufficient, and they have some advantages for components which are not fully accessible [2]. Since cracking effects on the dynamic properties of the structures, crack detection can be done with evaluation of these parameters. In this way, calculations are usually achieved using various numerical [3, 4] or analytical methods [2, 5].

For both numerical and analytical methods, some remarkable parameters such as natural frequencies, coefficient of the stress intensity and mode shapes are studied [6-9]. In Ref. [6], location and depth of the crack are estimated from the intersection of the normalized natural frequency (as a function of location and depth of the crack) and an experimental response. In Ref. [7], by using the strain energy density function, the additional flexibility in vicinity of the crack is evaluated, so a new finite element matrix is used to achieve dynamic response when a harmonic force is applied on a cracked free-free beam. Andreaus and Baragatti [8] considered contact surfaces to model non-propagating cracks for analyzing nonlinear behavior of a cantilevered beam. In this procedure, a sensor and driving load are required for crack

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