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Static and eigenvalue analysis of cracked Timoshenko beam by new macro element contained one crack

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Abstract

In this paper the finite element of beam element with a transverse crack is derived for fatigue and fracture applications. The new element is one-dimensional with an embedded edge crack in arbitrary position of beam element with any depth. The crack is not physically modeled within the element, but instead, its influence on the local flexibility of the structure is considerated by the modification of the element stiffness as a function of the crack depth and crack position. The derivations are based on a simplified computational model, where each crack is replaced by a corresponding linear rotational spring, connecting two adjacent elastic parts. The components of the stiffness matrix for the cracked element are derived using the superposition principle, compatibility relations, and Betti's theorem. The stiffness matrix for transversely cracked beam element is derived and all expressions are given in symbolic forms. Models using the presented stiffness matrix are shown to produce accurate results, although with significantly less computational effort than physical modeling of the crack in 2D finite element models.

Keywords: one crack, Static analysis, eigenvalue analysis, Timoshenko beam, macro element

1. INTRODUCTION

Cracks in structures present a serious threat to proper performance of structures. Most of failures of presently used structures are due to material fatigue. Experimental and computational studies have demonstrated that the presence of cracks leads to a change of the vibration properties of these structures [1–3]. Because, due to the crack presence, the structures miss their original stiffness. Monitoring the change of these properties over time represents a widely used nondestructive method of evaluating the severity of the damage and computing the remaining life of structure.

A detailed model of the crack and its surrounding can be properly obtained with an appropriate mesh of finite elements. From a computational viewpoint, the finite element method represents a standard approach to simulate how cracked structures treat under external loading. The majority of these methods introduce the crack by physically modeling the separation of the two crack faces. A major disadvantage of these methods is that they necessitate the allocation of significant computational efforts in order to accurately model the stress singularity at the crack tip. However, such an approach is unsuitable for inverse problems where a model suitable for crack location and depth modification is required when searching for a potential crack.

For some applications, the global response of a cracked structure is of interest, while the local behavior of the material in the vicinity of the crack tip can be disregarded. In such cases there is a need for simulating the crack presence without actually modeling the crack. In this paper we present such an approach applied to a one-dimensional finite element that has an embedded crack on each position of element with any depth. The conceptual illustration of the presented element with modified stiffness matrix is presented in Figure.1. The presence of the crack is introduced by changing the stiffness matrix of the element. This type of element can be used in structural applications to compute response of a cracked structure under loading. Also it can be used for eigenvalue analysis of structures.

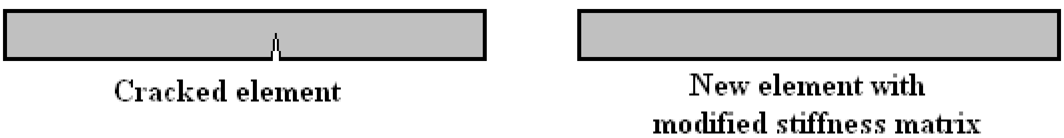

Figure. 1. Conceptual illustration for the new finite element: the crack is removed from the physical model and the stiffness matrix is modified