Detection of damage through coupled axial–flexural wave interactions in a sagged rod using the spectral finite element method

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Abstract
This paper presents the results of a computational and experimental validation exercise performed towards damage identification of a sagged rod with known damage by using the coupled axial–flexural wave interaction mechanics. Towards simulating the damage scenario in a sagged conductor made of steel wire rope, a prismatic steel rod is taken up for study. An initial axial wave, tangential to the curve of the arc, manifests as both axial and flexural waves as it propagates alongside the length of the rod. This interaction effect between axial and flexural wave propagation is studied in this paper. Impedance mismatch is made in the rod by changing its cross-sectional area along its length. Numerical simulations are implemented using the spectral finite element method with a combined axial and flexure effect. The concept of obtaining the exact spectral element dynamic stiffness matrix for a wave propagation analysis sagged rod is discussed. Computation is implemented in the Fourier domain using Fast Fourier Transform (FFT). In the time domain, post processing of the response is done, which is applicable in structural diagnostics in addition to the wave propagation problem. The predominant single-frequency-based amplitude-modulated, narrow-banded, burst wave propagation is found to be better matched if the elemental rod theory is replaced with a modified rod theory called the Love theory. The differences in the propagating waves allow identification of the damage location in a very clear-cut way. The methodology of the moving correlation coefficient is also successfully employed to detect the damage precisely. This fact is very encouraging for future work on structural health monitoring.

Keywords
Wave propagation, damage detection, spectral finite element method, sagged rod, axial–flexural wave interaction, moving correlation coefficient

1. Introduction
Damage is well-defined as a permanent variation in the mechanical state of a structural element or material that could possibly distress the performance. The process of implementing a strategy for damage detection and characterization of the current health of engineering structures is known as structural health monitoring (SHM) (Dawson, 1976), which is an interdisciplinary engineering field. It is an area of great technical and scientific interest. These techniques are, however, in an evolving state of development for civil engineering structures and are still developing (Giurgiutiu, 2008). Hence, research in this area is of paramount importance. The detection of damage in a complex structure is the most essential issue to deal with in SHM. It is still an overwhelming problem for practical applications, mainly in complex systems, partially due to the uncertainty caused by load.

Damage detection techniques are established based on wave propagation response in structures (Lee et al., 2007; Lepidi et al., 2009; Lakshmanan et al., 2010; Guo

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