THE MECHANICS OF HIGHER ORDER MODE SHAPE DERIVATIVES AS DAMAGE INDICATORS IN BEAM-LIKE STRUCTURES

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A great deal of interest has developed over the past few decades in developing methods to detect, locate, and quantify damage in civil infrastructure (i.e., structural health monitoring) by determining changes in a structure's modal vibration characteristics. Such methods are popular due to the relative ease in which vibration tests can be performed and the direct relationships that exist between structural properties and vibration-response properties. Excellent reviews of the literature related to structural health monitoring and damage identification methods based upon vibration changes are given in [1] and [2].

Among researchers who have utilized features associated with modal vibration properties of a structure, it is often concluded (*e.g.*, [3,4]) that changes in mode shapes, and particularly mode shape curvatures, are sensitive to the presence and location of damage and thus make good candidates for a damage identification feature. These sensitivity properties, however, have not been studied systematically and are often validated only by anecdotal results for specific structures [1]. In addition, it has been observed that relatively large levels of damage are used by many researchers when studying the sensitivity of mode shapes to damage [5], making it unclear whether the proposed feature would be capable of identifying incipient damage.

In this work, we undertake an examination of the behavior of higher order derivatives of modes shapes in the presence of damage. We restrict our analysis to beam-like structures whose dominant vibration modes are transverse. While this limits the scope and applicability of the results, they are still relevant to a significant class of structures, particularly bridges. We are particularly interested in formal estimates of the expected sizes of changes in mode shape derivatives due to damage with an eye towards identifying robust features. To this end, we show that the spatial extent of the damage relative to a mode's wavelength plays an important role in determining the level of change caused by damage. The role of mass loss due to damage is also studied. We perform numerical studies of the damaged vibration equations and use these results to motivate analytical approximations for the changes induced by damage. Finally, we discuss the utility of mode shape derivatives as damage identification features and make recommendations for features to consider.

References

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