Output-only Structural Health Monitoring of a Riveted Steel Railway Bridge utilizing Proper Orthogonal Decomposition, Artificial Neural Network, and Strain Measurements

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Abstract

This study presents a new scheme for autonomous health monitoring of railroad infrastructure using a continuous stream of structural health monitoring data. The study utilized measured strains from an optimized sensor set deployed on a double track, steel, railway, truss bridge located in central Nebraska. The most common failure mode for the superstructure of this structural system is the stringer-to-floor beam connection failure, which was the focus of this study. However, the proposed methodology could be used to assess the condition of a wide range of structural elements and details. The damage feature adopted in this framework was the variations of Proper Orthogonal Modes (POMs) of the measured structural response. To automatically detect the occurrence, location, and intensity of deficiencies from the POMs, Artificial Neural Networks (ANN) was adopted. POM variations, which are traditionally input (load) dependent, were ultimately utilized as damage indicators. To alleviate the variability of POMs due to non-stationarity of the train loads, a preset windowing of measured output was completed in conjunction with automated peak-picking. Furthermore, input variability necessitated implementing ANNs to help decouple POM changes due to load variations from those caused by deficiencies, changes that would render the proposed framework input independent, a significant advancement. Damage "scenarios" were artificially introduced into select output (strain) datasets recorded while monitoring train passes across the selected bridge. This information, in turn, was used to train ANNs using MATLABs Neural Net Toolbox. Trained ANNs were tested against monitored loading events and artificial damage scenarios. Applicability of the proposed, output-only framework was investigated via studies of the bridge under operational conditions. To account for the effects of potential deficiencies at the stringer-to-floor beam connections, measured signal amplitudes were artificially decreased at select locations. Finally, to validate the applicability of the proposed method using low-cost measurement devices, the measured signals were corrupted by high levels of white, Gaussian noises featuring spatial correlations. It was concluded that the proposed framework could successfully identify 20 damage indices, which were artificially imposed on measured signals under operational conditions.

Keywords

Structural Health Monitoring; Strain Measurements; Artificial Neural Network; Proper Orthogonal Decomposition; Non-stationary Excitation

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