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TITLE: REAL-TIME BOLT LOOSENESS CHARACTERIZATION USING EMI-BASED PZT SENSING NETWORK: A GCN PERSPECTIVE

ABSTRACTS

Bolted joints are the most vital parts in civil, mechanical and aerospace engineering connecting assemblies and transferring loads. Although subtle and frequently seen, the loosening of bolts can potentially lead to critical consequences, particular in transportation sector. Real-time monitoring of bolted joint conditions and identification of bolt looseness is therefore highly desired. Previous research has demonstrated that the bolt looseness can be identified through a variety of Non-destructive Testing (NDT) techniques including ultrasounds, optic-fiber sensors, vison-based approaches, etc. The Electro-mechanical Impedance measuring method has been proved as an effective NDT technique in detecting the bolt looseness with a single PZT sensor. The method is conducted by exciting the PZT element implemented on the host bolt structure with a series of periodic voltages at the ultrasonic frequency band and collect dynamic responses (electrical-mechanical impedance) from the PZT patch. Despite of the simplicity, the EMI method has been criticized of lacking exact correspondence between the change of EMI data and the structural variation, and therefore has been treated as more of a qualitative validation rather than a quantitative choice. Machine learning has been incorporated in some studies for more accurate EMI-based monitoring but the how a machine learning algorithm can be introduced to best reveal the value of the obtained EMI data is worth further investigating. This paper describes an experimental and data-driven study in quantitatively characterization of the residue torque and the loosening of a bolted joint with a pre-designed and implemented PZT sensing network. A Graph Convolutional Network (GCN) model is established for the PZT sensors. The GCN model is trained using the relationship between data from neighboring sensors and the topology structure of the sensing network rather than data from individual sensors, in a way to more precisely interpret the EMI signatures and correspond the variations to the bolt looseness with a quantitative confidence.

KEYWORDS

Electro-mechanical Impedance | Nondestructive evaluation | Bolt loose monitoring | Graph Convolutional Network | PZT sensing network |