**An Efficient Model-Assisted Probability of Detection Framework for Structural Health Monitoring Systems**

**Juan David Navarro1, Juan C. Velasquez-Gonzalez1, Mauricio Aristizabal1, Arturo Montoya1, Harry R. Millwater1 and David Restrepo1**

1The University of Texas at San Antonio

San Antonio, TX, 78229

david.restrepo@utsa.edu

ABSTRACT

Structural Health Monitoring (SHM) entails the implementation of sensor-based systems and advanced data analytics techniques to continuously monitor and assess the condition of structures. The capability of SHM systems of detecting structural damage is typically measured the Probability of Detection (POD) metric. However, traditional methods for obtaining POD curves in SHM systems often entail significant costs and time investment. In response, in this presentation we address these limitations and propose a new computational framework based on sensitivity analysis for obtaining the POD curve in guided-wave SHM systems. The new framework leverages the HYPercomplex Automatic Differentiation method (HYPAD) in conjunction with the Spectral Finite Elements Method (SFEM), the framework computes highly accurate arbitrary-order derivatives of wave propagation phenomena with respect to mechanical properties, geometry, electrical properties of piezoelectric transducers, and boundary conditions. These derivatives, derived through HYPAD-SFEM, are then utilized in a Taylor Series-based surrogate model to estimate the POD curve under nominal input conditions. Furthermore, to account for the POD transference between experimental settings and practical in-service conditions, the proposed surrogate model was used to predict the POD curve under varying input conditions. This POD transference was carried out without the need for additional simulations or experiments. The effectiveness of the methodology is showcased through two application studies: one involving a one-dimensional rod with a notched section. The second application study features a plate with a localized defect employing two piezoelectric transducers in a pitch and catch configuration. Overall, the HYPAD-SFEM framework, coupled with the Taylor series-based surrogate model, offers a novel and time-efficient approach for computing accurate POD curves in guided-wave SHM systems. Additionally, this approach facilitates the development of POD transfer functions, serving to bridge the gap between controlled laboratory testing and real-world operational conditions, thus advancing the practicality and reliability of SHM systems in ensuring structural integrity across diverse applications.

**Keywords:** Model Assisted Probability of Detection, Structural Health Monitoring, Surrogate Model