

## Simulation-Based Deep Learning Technique for Diagnosis of Bolt Jointed Plates Using PZT Sensors

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### ABSTRACT

Structural health monitoring (SHM) using piezoelectric (PZT) sensors plays a crucial role in real-time monitoring of the health status of structures, as it is a cost-effective, reliable, and easy-to-use method that can reduce operation and maintenance costs, improve system lifespan, and enhance safety in bolted mechanical systems. In this paper, we conducted both numerical and experimental studies on the vibration and output voltage frequency response of a skin plate with 8 bolt joints by varying the bolt tightening force and location. We confirmed that changes in bolt tightening force and location can affect the dynamic characteristics of the structure, which can be utilized to predict bolt loosening in the plate. Furthermore, we efficiently calculated the frequency response of the bolted plate using the model order reduction (MOR) method with Krylov subspace and constructed a heatmap-style MS similarity map for deep learning from the MS similarity function. We demonstrated that accurate diagnosis of initial bolt loosening in the plate is enabled using the trained convolutional neural network (CNN). This simulation-based deep learning approach can significantly contribute to structural health monitoring of bolt jointed and vibrating engineered systems.

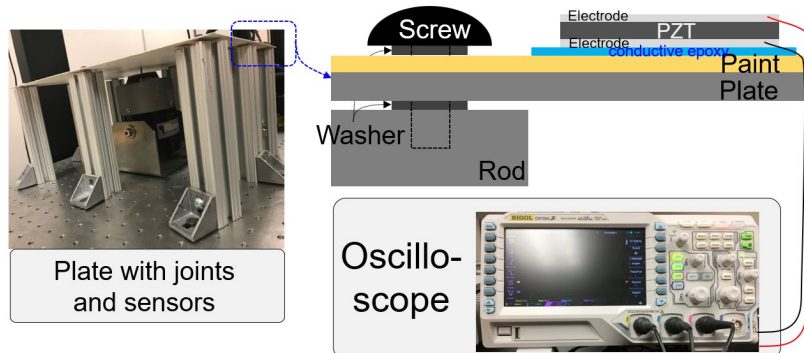


Fig. 1 Experimental setup for PZT voltage measurement of a bolt jointed plate

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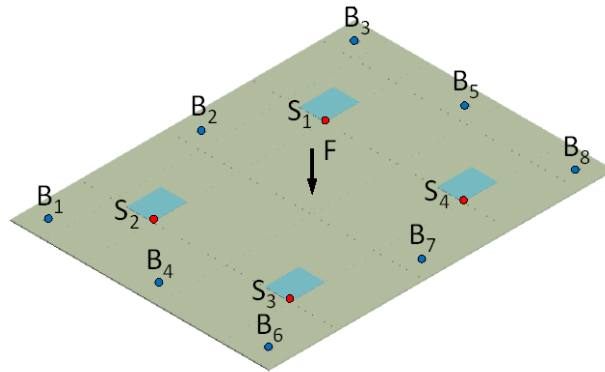


Fig. 2 Location of bolts and PZT patches on a bolt jointed plate

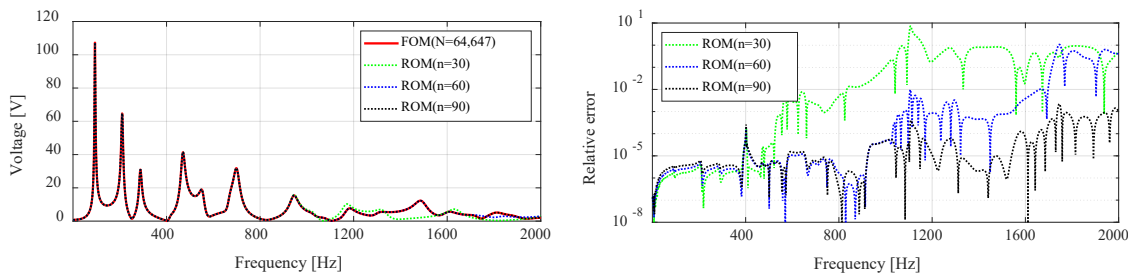


Fig. 3 Frequency response of output voltage at  $S_4$  using FOM and ROMs

## ACKNOWLEDGEMENTS

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education (No. 2020R111A3073275)

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