IMPEDANCE-BASED HEALTH MONITORING OF BOLTED JOINT

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1. Introduction

This paper presents the experimental investigation of impedance-based health monitoring technique of bolted joint. This technique utilizes the electro-mechanical coupling of piezoelectric material to detect changes in structural properties. A piezoceramic (PZT) actuator-sensor patch is bonded on the structure. Through the measurement of its electrical impedance, which is coupled with the mechanical impedance of the structure, the changes in the properties of the structure due to the changes of torque applied to the bolts can be monitored. The result obtained from this study can be used to develop the modeling and quantitative impedance-based health monitoring technique of bolted joint.

2. Impedance-based health monitoring technique

PZT has electro-mechanical coupling property. It generates electric charge when mechanical force is applied and conversely it mechanically deforms in the presence of an electric field. Previous studies [(1), (2)] show that the electrical impedance of PZT is directly related to the mechanical impedance of the structures being bonded and will be affected by the change in the structural properties, e.g. stiffness, damping, etc. The electrical impedance is measured at high frequencies. At high frequencies the wavelength of the excitation is small and sensitive enough to detect minor changes in structural properties. Therefore, by measuring the impedance of PZT the investigation in the structural properties can be made.

3. Experimental system

A PZT actuator-sensor patch is bonded at the center of a bolted-joint aluminum structure as shown in Fig. 1. The whole length of the structure is 1 m. The joint is at 0.25 m from one end. The aluminum bars have cross-sectional area of 30 mm x 1 mm. The detail of bolted joint is shown in Fig. 2. Four 5-mm-steel bolts with spring washers, washers and nuts are used. The total length of the bolted joint part is 80 mm. The PZT patch is wired to the impedance analyzer. A constant voltage of 10 V with varied frequency is used to excite the structure. The output current is measured, and then the electrical impedance, which is the ratio between the input voltage and the output current is calculated. Hence the electrical impedance for different values of torque applied to the bolts can be observed to investigate the change in structural properties.

In reality, structures are designed to resist external loading such as tensile force. The structural properties of bolted joint may be affected by the presence of tensile force. Hence electrical impedance is measured without applied tensile force and with applied tensile force of 98 N.

4. Results

Absolute value of impedance for different torques applied to the bolts is shown in Fig. 3. It can be seen that the change in the torque causes change in the impedance. Generally speaking, the resonance peaks of the impedance shift to higher frequency when smaller torque is applied. Height of the peaks is affected by the change of torque. Tensile force in the structure also causes significant change in the impedance. This result shows the ability of the impedance-based health monitoring and possibility of using this method in health monitoring of bolted joint. However the behavior of bolted joint in this high frequency range is complicated and need further investigation.

Keywords: Impedance-based health monitoring, Piezoelectric material, Bolted joint
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5. Conclusions

Impedance-based health monitoring of bolted joint was studied. Experimental result shows the ability of impedance-based health monitoring using piezoelectric material to detect the change in structural properties. The result can be used to develop the modeling and the quantitative impedance-based health monitoring technique of bolted joint.

References

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Figures

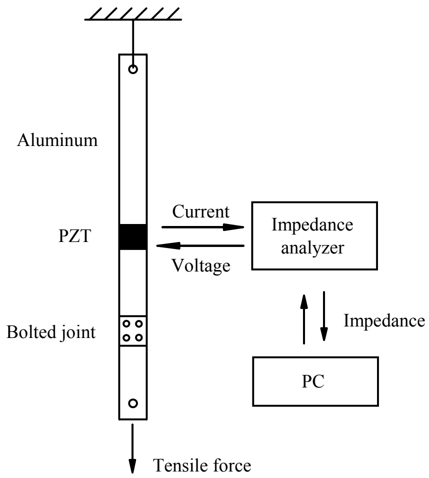

Fig. 1: Experiment system

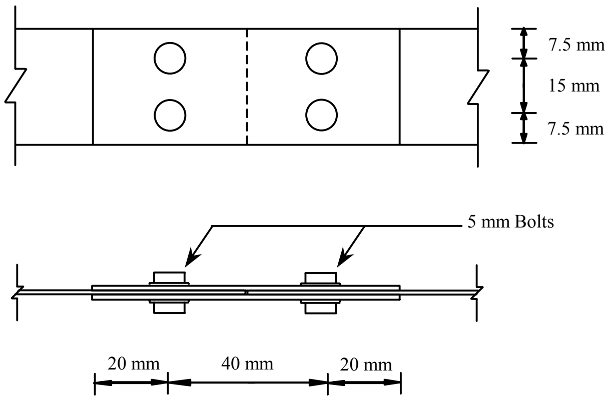

Fig. 2: Bolted joint detail

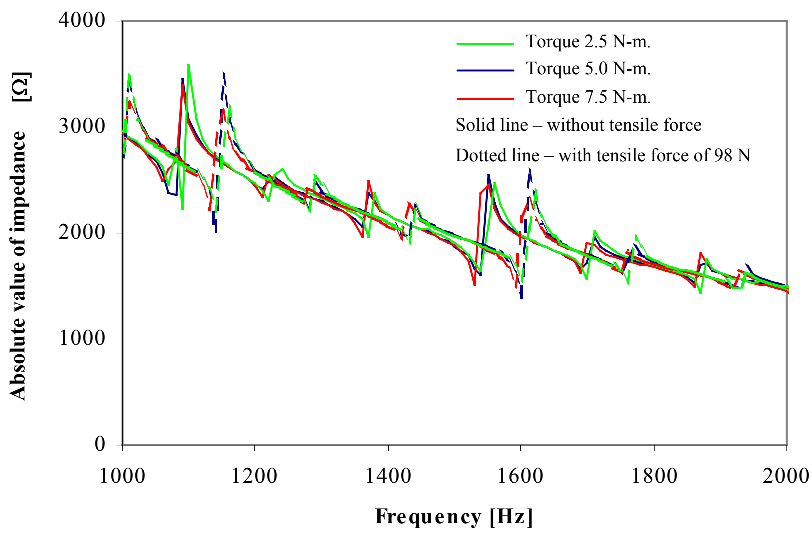

Fig. 3: Measured electrical impedance of the bolted joint