A novel vibration response-based approach to monitor faults in bolted complex structures

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Abstract. Since bolted complex structures are easily subjected to faults like fatigue crack/bolt loosening during their service, monitoring faults is very meaningful and helpful for them. Therefore, a novel vibration response-based approach to monitor faults in bolted complex structures is proposed in this paper. In the new approach, bolted complex structures are simplified as some discrete substructures, whose nonlinear dynamics are studied by a nonlinear multi-degree-of-freedom (MDOF) mode. By stimulating the structure many times with different magnitudes, nonlinear features from the substructure to be monitored only are defined, and a novel fault index and corresponding approach are proposed accordingly. With some experimental studies on a lab bolted complex structure, the effectiveness of the proposed approach is vindicated fully.

Introduction

For complex engineering structures, bolts are widely applied to to clamp different elements. However, they are easily subjected to faults like fatigue crack/bolt loosening during their service process since these bolted complex structures often work with dynamic loads like vibration and impact. Bolt faults not only affect structures' safety and reliability, and may cause some catastrophic consequences [1]. Therefore, monitoring bolt faults at an early stage is very meaningful and helpful to keep the healthy operation of bolted complex structures. For this objective, a host of vibration response-based methods have been proposed [2]. Their fundamental principle is that vibration response-based features depend on structural physical properties solely, any change in properties due to bolt faults can thus be monitored by monitoring changes in vibration response-based indexes [3]. Existing nonlinear vibration response-based methods provide much more information of complex structures with bolt faults. However, one obvious limitation is that data from health structures are required during the implementation of methods. This would affect these methods' effectiveness if data of health structures are not known. To consider this issue, a novel vibration response-based approach to monitor faults in bolted complex structures is proposed in this paper. The main novelties of this paper are: i) Stimulating the structure to be monitored only, and using nonlinear vibration responses, local fault features are derived; ii) With fault features, a novel approach with a sensitive fault index is proposed, and its availability is illustrated through experimental cases on a lab bolted complex structure (Figure 1).

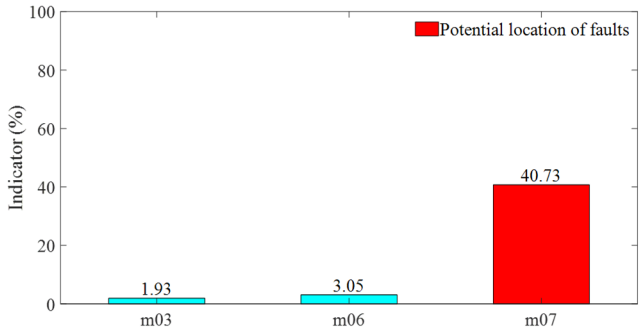

Figure 1: Diagnosis results related masses.

Results and discussion

By considering effect of faults as nonlinear restoring loads, discrete MDOF model with nonlinear elements can be built for the dynamic analysis of bolted complex structures.
Stimulating the structure many times, similar equations from the substructure to be monitored can be applied to form a local and sensitive vibration response-based fault index.
Results from experimental studies on a bolted complex structure with a loosening fault show that the novel approach can give more correct location of faults in the structure.

References

[1] Bickford J. (2018) An introduction to the design and behaviour of bolted joints, revised and expanded. Routledge, NY.
[2] Huang J., Liu J., Gong H., Deng X. (2022) A comprehensive review of loosening detection methods for threaded fasteners. *Mech. Syst. Signal. Rr.* **168**:108652.
[3] Nikravesh S.M.Y., Goudarzi M. (2017) A review paper on looseness detection methods in bolted structures. *Lat. Am. J. Solids Struct.*, **14**:2153-2176.