6th European Conference on Computational Mechanics (ECCM 6)
7th European Conference on Computational Fluid Dynamics (ECFD 7)
11 – 15 June 2018, Glasgow, UK

Anomaly detection in mechanical structures exploiting the inverse Finite Element Method

Luca Colombo[1] (*), Claudio Sbarufatti[2] and Marco Giglio[3]

[1] Politecnico di Milano, via La Masa 1 Milano, luca1.colombo@polimi.it
[2] Politecnico di Milano, via La Masa 1 Milano, claudio.sbarufatti@polimi.it
[3] Politecnico di Milano, via La Masa 1 Milano, marco.giglio@polimi.it

Key Words: *iFEM, Anomaly Detection, Crack, Damage identification.*

One main limitation to the implementation of Structural Health Monitoring (SHM) systems in real structures is the influence of different boundary conditions with respect to those adopted during SHM system design, especially for what concerns the loads, potentially leading to damage misclassifications. In this context, the inverse Finite Element Method (iFEM), recently developed by Dr. A. Tessler for *shape sensing* of shell structures, can be used to reconstruct the displacement field, thus the strain field, everywhere in a component on the basis of just few strain sensors placed in discrete positions and without requiring any a-priori knowledge of loads or material properties. It is based upon the minimization of a weighted least-squares error functional defined as a comparison between the experimental strains and a corresponding numerical formulation of the same, leading to a system of the type $KU=F$ that closely resembles the direct FEM one.

This work proposes a methodology to perform SHM exploiting the iFEM algorithm for strain reconstruction. In particular, an anomaly index is defined based upon the comparison between the strain read at a target sensor location and the one reconstructed, in the same position, through the iFEM algorithm. When the analyzed structure is in a “healthy” condition, the two values match, otherwise they do not. The defined anomaly index enables to identify both the presence and the position of a defect within the structure without being dependent on the modelled boundary load condition. Computation efficiency is ensured by the iFEM algorithm itself. A very fast reconstruction of the component strain field is achieved once a sensors grid is established within the structure, meaning the method can be easily implemented in an online monitoring system. In fact, the matrix K of the final system depends just on the sensor configuration and not on the strain values, thus it can just be inverted once and offline. Though the method formulation is general for an arbitrary component geometry and damage type, the proposed methodology is experimentally tested by means of a clamped plate subjected to fatigue crack propagation. The results underline the method attractiveness for its ability to correctly detect both the presence and the location of the damage without any prior information on the boundary load condition and with a low computational effort.

REFERENCES

[1] Cuong C.Quach and Sixto L.Vazquez, Alex Tessler, JASON p.Moore, Eric G. Cooper and Jan L. Spangler. "Structural anomaly detection using fiber optic sensors and inverse Finite Element Method." *AIAA*. San Francisco, California, 15-18 August 2005. 8.

[2] Kefal, Adnan. "A quadrilateral inverse-shell element with drilling degrees of freedom for shape sensing and structural health monitoring." *Engineering Science and Technology, an International Journal* (2016): 1299–1313.

[3] Spangler, Alexander Tessler and Jan L. "A least-squares variational method for full-field reconstruction of elastic deformations in shear-deformable plates." *Computer methods in applied mechanics and engineering* (2005): 327–339.