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A Modified Dual Kalman Filter approach for damage detection using distributed optic fiber measurements

Sahar Farahbakhsh¹, Ludovic Chamoin^{1,2} and Martin Poncelet¹

¹ Université Paris-Saclay, CentraleSupélec, ENS Paris-Saclay, CNRS, LMPS, Laboratoire de Mécanique Paris-Saclay, 91190, Gif-sur-Yvette, France
sahar.farahbakhsh,ludovic.chamoin,martin.poncelet@ens-paris-saclay.fr

² IUF, Institut Universitaire de France, 1 rue Descartes, 75231 Paris CEDEX 5, France

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Structural health monitoring is an essential element of engineering, enabling anomaly detection and risk assessment in mechanical systems. Critical structures are increasingly equipped with sensors to continuously monitor their state and track their damage progression. Advanced monitoring techniques can thereby improve the overall safety and durability of structures by making real-time adjustments to service loads. In addition, measured data can be utilized to create a digital twin of the structure and provide insights into the physical phenomena impacting it [1].

Updating the associated numerical model involves solving an ill-posed inverse problem in a sequential manner. The modified Constitutive Relation Error (mCRE) may serve as a robust tool for this purpose. In this method, equilibrium equations, sensor locations and known boundary conditions are considered reliable information, whereas constitutive relations, poorly known boundary conditions and measurement data are treated as less reliable. The reliable information is enforced in the formulation while the less reliable information is relaxed [2]. These features render the mCRE a robust identification method, especially in the presence of noisy or corrupted measurements [3]. Additionally, analyzing the model error term within the mCRE formulation enables the identification of areas with significant error, allowing for adjustments in the parametric space accordingly.

Integrating the mCRE into a data assimilation framework by means of a coupling with Kalman filtering results in a model updating method called the Modified Dual Kalman Filter (MDKF) [4, 5]. This approach maintains the necessary sequentiality required for on-the-fly system monitoring and compensates for the susceptibility of classic Kalman filters to noisy measurements. Moreover, the MDKF method is well-suited for real-time applications as it does not necessitate an iterative procedure for parameter identification.

In the present work, Distributed Optical Fiber Sensors (DOFS) are embedded in concrete beam specimens undergoing a quasi-static 4-point bending test. The acquired data is utilized within the MDKF framework to identify model parameters and detect potential damage at each stage of the process. Furthermore, the mCRE functional's model term component is analysed to identify areas with significant modelling error, and subsequently adjusting the parametric space using the Cartesian grid Finite Element Method (CgFEM) [6]. The validation of the MDKF outcomes is achieved through comparison with damage detection results obtained from Digital Image Correlation (DIC) on the samples.

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