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On Non-destructive Material Parameter Identification using Full-field Measurement

An Anisotropic and Local Strain Reconstruction Method and a General Inhomogeneous Virtual Fields Method

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On Non-destructive Material Parameter Identification using Full-field Measurement: An Anisotropic and Local Strain Reconstruction Method and a General Inhomogeneous Virtual Fields Method

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Over time, existing bridges in Germany and around the world are subject to material ageing and fatigue. Their safety needs to be assessed. Non-destructive material parameter identification using full-field measurement is helpful for the assessment. The identification requires the strain reconstruction from the displacement measurement and the expression of the material parameters, where cracks and damage should be considered in the context of ageing and fatigue. In this thesis, two approaches are developed addressing these requirements. They are the Anisotropic and Local Method (ALM) for full-field measurement reconstruction and the general Inhomogeneous Virtual Fields Method (IVFM) for parameter identification. A combined use of both methods is expected to provide a more accurate assessment.

The ALM reconstructs a local function from noisy and discrete measurement within an adaptively evolved anisotropic window for each data point. To determine the anisotropic window, an algorithm is developed to guide the evolution of the window from a single point to an appropriate shape and size for sufficient regularisation. The algorithm is given to both 1D and 2D. A fast computation scheme that replaces pointwise estimates with windowed estimates in variance-based fusion is also proposed. In addition, a physically meaningful indicator of discontinuities according to the reconstruction property is introduced. The validation of the ALM is demonstrated by its application to synthetic data in both 1D and 2D, as well as to displacement measurement from cyclic loading tests. A comparative study of different methods on synthetic data shows the higher accuracy of the ALM and the applicability of the fast scheme. Its application to experimental data successfully identifies the cracks and the reconstructed result shows satisfactory agreement with expectations in terms of fracture mechanics.

The IVFM is a general form of variance minimisation-based VFM for both homogeneous and inhomogeneous identification. Its generality is reflected in two ways. First, each material parameter is described spatially with individual distribution functions. Second, the distribution functions are unified into discrete matrix forms regardless of their type. In particular, a direct construction of a Finite Element (FE) based distribution matrix is given. A performance study of the IVFM, in terms of both computational efficiency and identification accuracy, is carried out based on 270 synthetic cases. The studied variables are the stiffness distribution, the loading condition, the measurement resolution, the distribution function type and the number of coefficients in it. The study shows that independently of the stiffness distribution and the load condition, an overall stiffness estimate can be plausibly given by a homogenous identification. However, an inhomogeneous identification depends on the load condition that affects the domain activation. It is also seen in most of the studied cases, the IVFM with an FE-based distribution has a more satisfactory performance than those with either regular or Chebyshev polynomials.