Abstract

The material parameter identification problem, an inverse problem, typically aims to determine unknown functions (parameters) from an imperfectly known system response. Numerical solutions of such problems have great practical significance in diverse engineering applications, namely seismic imaging, biomechanical imaging, material characterization, structural health monitoring, seismic exploration. The most common route to solve these inverse problems is to minimize the error between calculated and measured response in a least square sense. Typically, quasi-Newton methods are preferred due to its less computational cost in case of large-scale identification problem, although, the convergence rate of Gauss-Newton method is faster compared to quasi-Newton method. However, the main problems associated with least square minimization of the error functional are its non-convexity and proximity to initial guess. In recent years, another technique for elastic parameter estimation was proposed based on the concept of error in the constitutive equation (ECE). In contrast to the standard least square based functional, ECE cost functional measures the error in constitutive equation due to two incompatible stress/moment and strain/curvature fields in an energy norm. Error in constitutive relation arises when stresses and strains are incompatible to each other and generated following two dissimilar constraints. In this thesis, we have explored and proposed few improvements of the ECE based parameter identification approach for general linear anisotropic and nonlinear elastic material. In particular, we have proposed a trace norm minimization of the constitutive discrepancy functional within the standard ECE procedure that results in explicit linear material update formulae for general anisotropic linear elastic material. A simple penalization technique is used to incorporate measured response, which introduces regularization to the inverse problem via penalization parameter (more strictly inverse of regularization parameter). An effort is also made to identify restrictions on measured response for reconstruction of some common anisotropic materials based on proposed update procedure. A fair comparison with the standard least square based method reveals the computational advantage of the ECE based procedure. Homogeneous or heterogeneous identification of 2D orthotropic and 3D isotropic or orthotropic thermo-mechanical material parameters are also successfully solved within the proposed ECE framework. In case of parameter estimation from frequency domain elasto-dynamic response we propose an uncouple form of the standard ECE procedure that does not require to solve an extended couple system. Then an experimental verification is also achieved by detecting local damage of a cantilever aluminum plate. The proposed ECE based identification technique is also applied in detecting inclusions by heterogeneous reconstruction of material parameters for different nonlinear materials. Numerical and experimental results demonstrate that the proposed ECE based identification method can successfully reconstruct the spatial distribution of linear or nonlinear elastic material parameters from partial and noisy measurements.

Keywords: Error in constitutive equation, MECE based updating approach, isotropic and orthotropic elastic parameter, thermo-mechanical coupling, inverse damage detection technique, hyperelastic material