2D Inverse Finite Element Procedure for Recovering a J2 Plasticity Material Model

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Material models are the key ingredients to accurately capture the global mechanical response of structural systems. The use of finite element analysis has proven to be effective in simulating nonlinear engineering applications. However, the choice of the appropriate material model plays a critical role to the value of the numerical prediction. Conventional material modeling uses mathematical formulas to describe material behavior. Such formulas may have limited capability in capturing all of the inherent material phenomena involved.

Alternatively, the measured global response at specific domain or surface points can be used to guide the nonlinear finite element analysis to extract back a representative material model. The general approach that is widely used to solve this type of inverse problems is based on an optimization process that minimizes the error between measured and calculated response in terms of the parameters to be identified. An averaging technique, like the least squares, and a minimization technique, like the genetic algorithm, is typically needed by standard inverse analysis procedures [1]-[3]. In this study, a procedure that is independent of any averaging or minimization technique is presented. By imposing the measured displacement at the monitoring points on to the solution that uses an approximate material model, a set of modified stress-strain data points are generated throughout the domain. This is accomplished by applying two conjugate analyses of load and displacement control. The load control analysis is used as a stress-predictive computation and the displacement control analysis is applied to correct for strains. The stress-strain vectors at the most highly stressed integration point is then selected to establish an adaptively improved material model. This model is updated and used within a multi-pass incremental nonlinear finite element analysis until the discrepancy between the measured and the predicted mechanical response at the monitoring points is minimized leading to a suitably recovered material model. The J2 flow theory of plasticity with isotropic hardening is used as a framework to build the tangent constitutive matrices.

The applicability of the proposed approach is demonstrated by solving 2D inverse continuum problems with coupled stresses and strains. The comparisons presented support the effectiveness of the proposed approach in accurately extracting nonlinear material models for such problems. The strategic selection of the location of monitoring points helps attain more accurate and efficient predictions.

References

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