INELASTIC RESPONSE ANALYSIS OF STRUCTURES

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SUMMARY

Structural design relies in general on two considerations, serviceability under operating conditions and structural integrity under hypothetical overload conditions. Severe loading and environmental conditions of reactor components thus make inelastic analysis mandatory, i.e. creep, low cycle fatigue at elevated temperature as well as failure within the frame of safety considerations provide the essential background in the decision making process. For complex structures the success of the inelastic response analysis depends on many factors, but primarily on the development and integration of relevant constitutive models in the numerical solution of the non-linear boundary value problem, whereby the predictive value of the mathematical simulation must be assessed by experimental verification.

The objective of this paper is to illustrate the interaction of these disciplines with emphasis on constitutive modeling and numerical solution techniques using finite elements. In particular, fracture phenomena are examined as well as viscoelastic-viscoplastic behaviour in the light of a unifying internal state variable theory.

In the first case a stochastic fracture hypothesis is applied to model cracking by energy probability theory. The stochastic simulation of tensile strength provides a tool to account for size effects and more important for increasing strength in non-uniform stress fields which are both common phenomena of brittle materials. The probabilistic model is introduced for two reasons, (i) to overcome the shortcomings of deterministic models in which brittle failure is solely a function of stress (e.g. no tension materials) and (ii) to improve the efficiency of the numerical solution scheme.

In the second case the internal state variable theory is examined with regard to its structure for predicting aging, rate and history dependence in conjunction with necessary experimental input data. A computer oriented constitutive model is developed which provides a unified approach for elasticity, viscosity and plasticity without storage of history effects.

Several examples are given to illustrate the performance of both constitutive models in different classes of inelastic response regimes. In particular, brittle fracture is studied in the context of limit load analysis of structures with increasing complexity, starting from thick-walled concrete cylinder to prestressed concrete reactor vessel and reactor top closure. Alternatively, elastoplasticity is shown to be the limiting case of elastoviscoplastic behaviour when time effects approach stationary values, while creep is modeled either within the frame of linear and nonlinear viscoelasticity or viscoplasticity. To this end the example of a thick-walled cylinder is augmented by the creep study of a steel pressure vessel component.