

## FINITE ELEMENT ELASTIC-PLASTIC ANALYSIS OF LMFBR COMPONENTS

A. LEVY, A. PIFKO, H. ARMEN, Jr.

*Grumman Aerospace Corporation, Research Department, Bethpage, New York 11714, U.S.A.*

### SUMMARY

Finite element programs which include the effects of plasticity and creep should play a major role in verifying the structural integrity of LMFBR components under high temperature and pressure loadings. Accordingly, we have incorporated various features into the HEX module of the Grumman PLANS finite element program as a first step in developing state-of-the-art software to analyze nuclear reactor structural problems. The purpose of the present work is to develop methods for analyzing the isothermal elastic-plastic response of thick and thin shells under mechanical and thermal loadings where the emphasis is placed on accurate results with computational efficiency. This will eventually be followed by the introduction of non-isothermal creep including temperature dependent material properties.

The HEX module utilizes an eight to twenty node isoparametric hexahedron element with orthotropic material properties. The "initial strain" concept is employed to account for plasticity. Hill's yield criterion for orthotropic materials is employed to predict initial yield and in the subsequent flow rule. Further, a modified kinematic hardening theory of plasticity is used to provide for cyclic loading of materials whose yield stress varies with the accumulated plastic strain. Mechanical and thermal loading conditions are allowed to change in the course of a nonlinear analysis.

Using double precision calculations on an IBM 370 computer we are able to successfully analyze thin shell structures (ratio of radius to thickness = 500:1) composed of elements whose aspect ratios are 1000:1:1.

The program utilizes a variable number of stress points within an element. Gauss and Lobatto (in which boundary points are included in the set) points are used. The finite element idealization is chosen compatible with the total mechanical strain variation and the stress points are chosen to provide an accurate representation of the arbitrary plastic strain variation. Utilizing this procedure the number of degrees of freedom are kept to a minimum and, at the same time, the elastic-plastic boundary can be described to a high degree of accuracy. This results in maximum efficiency and accuracy of elastic-plastic analyses. Two problems used to demonstrate this capability are (1) a simply-supported beam uniformly loaded to collapse and (2) a cylindrical-toroidal-spherical thin shell test model to be tested by ERDA at ORNL and which represents a typical LMFBR component.

Accurate thermal-stress analyses can be obtained by using a concept in which the temperature distribution is represented to the same degree of accuracy as the displacement variation. The temperature and corresponding thermal strain at any stress point within an element are calculated from the applied temperature variation. Sample problems show that this leads to accurate results for elastic-plastic thermal problems.

### *Closing Statement*

The use of variable stress points within an isoparametric hexahedron allows for an accurate description of the plastic strain variation and temperature distribution with a minimum number of degrees of freedom. The HEX module can now be used to analyze thermal elastic-plastic problems of thin and thick shells with great accuracy and efficiency. This is an important step in developing a general purpose finite element program to analyze nuclear reactor components under non-isothermal conditions.