THREE–DIMENSIONAL NONLINEAR ANALYSIS OF MULTICAVITY PRESTRESSED CONCRETE REACTOR VESSELS

K. C. CHEUNG, R. C. YOUNG

General Atomic Company,
P.O. Box 81608, San Diego, California 92138, U.S.A.

SUMMARY

A technique for predicting the overpressure behavior of multicavity prestressed concrete reactor vessels, based on a modified three dimensional finite element analysis procedure, is presented. In this method, traditional isoparametric brick, membrane and rod elements are used to model the concrete, liners and reinforcing steel. The nonlinear effects of concrete cracking and metal plasticity, however, are incorporated into the governing equations through modifications to the original linear matrix at significantly lower computational cost than traditional methods. This approach permits cracking and plasticity effects to be continuously incorporated throughout the analysis providing a solution close to the true equilibrium path.

Several concrete failure criteria are examined. Analytical predictions are compared with experimental test data of a reinforced deep beam to determine the suitability of the failure criteria as applied to the overpressure behavior of the PCRV. The investigations also demonstrate the validity of the formulation and the efficiency of the solution schemes.

Finally, the analysis of a multicavity PCRV model subjected to monotonically increasing internal pressure is described. The test model is a 1/20th scale representation of the PCRV for a High Temperature Gas-Cooled Reactor. The model consists of a main central cavity and six smaller cylindrical cavities in the vessel wall. Prestressing of the model was accomplished by vertical unbonded high tensile bars and wire wrappings wound around the exterior of the structure under tension. The cavities were lined with steel plates and representative reinforcement was included in the model. The model was instrumented to measure deflection and strain data during prestressing and pressurization to failure. Pressure loading was applied hydraulically to all cavities. The test model is accepted to provide a valid base to evaluate the structural characteristics of a multicavity PCRV. Invoking the condition of symmetry, only 1/12th of the top half of the model is considered in this analysis. Good correlations between analytical and experimental results are obtained. A reliable and efficient technique of predicting the nonlinear behavior of the multicavity PCRV under hypothetical overpressure is demonstrated.