HYDRO-ELASTIC CALCULATIONS OF THE DYNAMIC RESPONSE OF A REACTOR TO A SUDDEN LOSS OF COOLANT

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SUMMARY

If one of the cold legs in a pressurized water reactor should suddenly break, a rarefaction wave would proceed into the downcomer, eventually penetrating into the core region. During this transient the pressure differential on the core support barrel would cause it to deflect, thereby modifying the pressure differential. Designers have accounted for the coupling of the fluid and shell motions only in an approximate fashion. In this paper a coupled analysis is described in which a two-dimensional, two-phase, hydrodynamic code, SOLA–DF, is coupled to a finite-difference shell code, FLX, to form SOLA–FLX. In this system the pressure computed by SOLA–DF acts as a forcing function for the shell motion and, in turn, the shell velocity is imposed as a boundary condition on the fluid dynamics. The coding of the coupled equations uses about 25,000 words of storage, and an additional 110,000 words are required for stor- age of the computational arrays. Problems can be run in as little as 3 minutes on the CDC 7600.

The SOLA–DF code has been verified by comparisons with experimental data and theoretical results. The treatment of phase transitions requires that a characteristic bubble number density and a model for bubble growth be assumed. With appropriate choices for the phase transition parameters, reasonable agreement with experimental data is obtained, but the theory is under continuing development. In the case of initially subcooled water, and for the times of interest, flashing at the pipe rupture must be described as a non-equilibrium process in which the break pressure drops significantly below the saturation pressure. We have concluded in a separate analysis, however, that the shell velocities are not high enough to cause local internal boiling. This allows the resolution of the finite-difference scheme to be much coarser than if boiling occurred.

Although the FLX code involves a straightforward differencing of the Timoshenko equations of cylindrical shell motion, to obtain reasonable accuracy it was necessary to develop a special treatment of the boundary conditions in which the deflection was fit with a cubic polynomial at the fixed end of the shell to impose accurately the condition of vanishing slope and deflection. Similarly, the bending moment was fit with a cubic at the free end of the shell to impose vanishing bending moment and shear. With this treatment we examined the first four axisymmetric natural modes and found that they are maintained to better than one part in 10,000 after several periods. The influence of lugs at the lower end of the core support barrel was examined for simple loadings and it was found that their effects are very local, and do not significantly modify the stress at the upper, fixed, end.

Results of these coupled calculations are being compared with 1/25 scale experiments being conducted at Systems, Science and Software. Tests with pressurized water at both ambient and reactor temperatures and with scaled and extra-thick core support barrels are planned. Preliminary results indicate that the coupling somewhat reduces the peak stresses in comparison with those determined when the influence of the core barrel motion on the fluid is not accounted for.