FLUID-SOLID INTERACTION BY FINITE ELEMENT TECHNIQUES

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SUMMARY

An investigation of the interaction between a mass of fluid and a rigid ring has been performed. The purpose of this study was to model possible interactions in a Boiling Water Reactor. The finite element method was employed, because of the large flexibility it presents. Different modeling techniques were tested for their applicability for fluid analysis.

The phenomenon of interest are the resulting force and pressure exerted on a rigid ring as it is impacted by a slug of fluid. The Reynolds number of the system was 10^7. The fluid is treated in the finite element formulation as a solid continuum. It is given fluid characteristics by choosing the Poisson ratio, Young's modulus, shear modulus and density. An inviscid, incompressible fluid with the correct bulk modulus and density can be modeled. The interaction was treated by using gap elements. These elements have the property that they have no resistance to tension, but infinite resistance in compression. Using these elements between the fluid and the ring, the interaction was modeled such that for fluid in contact with the ring the fluid could move tangetially to the ring without friction. A study of the discretization error associated with the contact phenomenon was performed. It was determined that with a refinement of the finite element mesh in the neighborhood of the ring, a continuous force could be determined.

The maximum force exerted on the ring occurred shortly after the initial contact. With time the force reached a lower level asymptotically. The behavior of the ring when different amounts of fluid in the model were used was investigated. It was determined that only the fluid near the region of contact was of influence to the ring. Also, the boundary conditions imposed away from the contact did not influence the maximum force that the ring was subjected to.

Different temporal integration schemes were studied to determine their applicability to this type of interaction analysis. The bulk behavior of the fluid and ring interaction was to be analyzed by this study. The wave phenomenon is not of interest, rather, the momentum transfer is of interest. The Newmark Beta Operator was found to be unacceptable for this analysis. Using this technique high frequency waves caused an instability in the solution. This could have been overcome by using the costly method of a much reduced time step. Modal techniques were then tested, this method would have eliminated higher frequency effects by assuming the solution could be formulated by using lower frequency modes. This technique failed because as the fluid contacts the ring the Eigenvalues of the system changes. This discontinuity was considered too severe for further study. The integration scheme that was used was the Houbolt Operator. This method is based on the use of cubic through three previous points and the current unknown point in time. Using this technique, a continuous solution as a function of time was obtained.

This study was able to capture the phenomenon of the interaction between a slug of fluid and a rigid ring. The force exerted on the ring as a function of time was obtained for points along the ring. Using an indirect method, the normal pressure exerted on the ring was calculated to be 4,000 psi. The modeling techniques used are applicable to problems of a similar nature. Fluid-solid interaction problems can be solved using finite element techniques if judicious choice is made concerning model definition and solution techniques.