Added Mass for Beam Mode Response

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SUMMARY

In 1972 a method was presented for evaluating the added mass of fluid contained between two long co-axial cylinders. The resulting equations have been widely quoted in the literature, and the resistive forces obtained from these expressions have been utilized extensively in seismic and LOCA studies to demonstrate design integrity. The present study extends the analysis to less idealized design configurations in which a finite annular geometry is subjected to a velocity that is a function of the axial coordinate. The theory includes the capability to model the effect of any combination of closed-open axial boundary conditions on the fluid and to compute the added mass associated with motion of either or both of the radial boundaries.

For the irrotational flow of homogeneous, frictionless, incompressible fluid, the desired potential is obtained by solving Laplace's equation. Constraints on this solution are specified at the axial coordinates denoting the ends of the annulus and at the inner and outer annulus radii. These conditions prescribe either open or closed axial boundaries in combination with axially varying radial velocities on the walls of the annulus. The later quantities are arbitrary since they are expressed as infinite series each term of which is the product of a time dependent coefficient and an axial mode shape of the problem. The solution proceeds by solving for the desired potential via separation of variables, differentiating the solution with respect to the temporal variable to obtain the hydrodynamic pressure and integrating this equation with respect to the angular and axial variables. Substitution of the inner and outer radii into the resulting equation gives the hydrodynamic forces on the annular boundaries. The desired added mass terms are the coefficients of the two time dependent functions in each of these expressions.

For the case of the closed-open axial boundaries and a non-zero, axially invariant acceleration on the inner wall, the added mass computed by the present theory is identical to that calculated in a previously published study which was restricted to the cited boundary conditions. The expanded capability of the present analysis is illustrated by a numerical example in which the specified acceleration at the inner radial boundary is a sinusoidal function of the axial dimension. Numerical results illustrate the dependence of the added mass on the system geometry.