VIRTUAL MASS EFFECT OF WATER ON THE INTERNALS OF PRESSURIZED WATER REACTORS. THEORY AND EXPERIMENTAL RESULTS

J. G. ALIBAUD

Babcock & Wilcox Company, Nuclear Power Generation Division, Lynchburg, Virginia 24505, U.S.A.

SUMMARY

One of the effects of water on the vibration of coaxial cylinders is the virtual mass effect. It can reduce the natural frequencies of some reactor internals by a factor of 4 or 5. The lowered frequencies may fall within the most dangerous range of the flow-induced pressure fluctuations.

A general theory will be presented for finite coaxial cylinders coupled by a compressible, axially flowing, irrotational fluid. By using the generalized equations of motion for the cylinders in vacuo and the potential fluid equation with the relevant boundary conditions, the equations for a very general system of coupled coaxial cylinders are derived with some restrictions. The hydraulic coupling is discussed and it is shown that the equations are greatly simplified when some conditions met in practical applications are fulfilled. Mathematical expressions for the generalized virtual masses and hydraulic coupling terms are derived for various radial boundary conditions for the fluid (internal fluid, annulus, infinite external fluid) and are shown to be in agreement with previously published theoretical results. Some kind of radiative and momentum transfer hydraulic damping which appears in the equations is discussed. The frequency ranges where the compressibility of the fluid is either important or not are determined with an intermediate region centered around the coincidence frequency.

The generalized virtual masses are a function of the cylinders' modes shapes; a simple case is that of the so-called "simply supported" cylinder. Formulas and tables will be given to calculate the virtual masses and natural frequencies changes of such a cylinder (or a combination of cylinders).

Experimental confirmation of the frequency shift will be obtained from a laboratory test on a simple cylinder and also from a field test of a first-of-a-kind reactor during its pre-operational test.

The laboratory cylinder (length: 44 in.; diameter: 22 in.; thickness: 0.125 in.; external water annulus thickness: 1 in.) experienced a reduction in frequency by a factor of 4 to 5 for the lowest modes. The maximum discrepancies between the calculated and measured shifts is of the order of 8%.

The field test was made on the thermal shield of a reactor prototype. The reduction in frequency between the in-air and the in-water conditions was of the same order of magnitude.

This paper reassembles and generalizes the results on the virtual mass effect of water on the natural frequencies of cylinders. These results were dispersed in the literature. Experimental confirmations are provided. The prediction of this effect of the water is an important step in the design for vibration.