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Evaluation of Fluid-Modeling Techniques in the Seismic Analysis of LMFBR Reactors*

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Fluid modeling is of great importance in the seismic analysis of the LMFBR primary system. If the fluid model used in the analysis is too simplified, the results could be very uncertain. On the other hand, if the model is too detailed, considerable difficulty might be encountered in the analysis. The objectives of this study are to examine the validity of the two commonly used fluid modeling techniques, i.e. simplified added mass method [1] and lumped mass method [2,3] and to provide some useful information on the treatment of fluid in seismic analysis. The validity of these two methods of analysis is examined by comparing the calculated seismic responses of a fluid-structure system based on these two methods with that calculated from a coupled fluid-structure interaction analysis in which the fluid is treated by continuum fluid elements.

For the purpose of illustration, the fluid-structure system considered in the analysis is a 2-D fluid-tank system. It consists of two 2-D plane strain beams (thickness = 2.54 cm) filled with an incompressible and inviscid fluid as shown in Fig. 1.

In the coupled fluid-structure model, the fluid region is modeled by the continuum fluid elements as shown in Fig. 2a. The dynamic response is obtained from the simultaneous solution of a set of coupled fluid-structure equations.

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In the lumped mass model shown in Fig. 2b, one half of the total fluid mass is uniformly distributed on each beam. This is accomplished by modifying the mass density of the structure. The lumped mass model considers only the fluid inertial effect; it ignores the fluid coupling effect.

The simplified added mass model has the same configuration as lumped mass model. The fluid mass is considered as an added mass, but it is calculated differently. The simplified added mass matrix is calculated by applying a constant acceleration on the beam 1 of the coupled fluid-structure model, while beam 2 is fixed. The fluid inertia and coupling forces acting on beams 1 and 2 are then computed by integrating the resulting boundary pressures on the beams 1 and 2, respectively. It is a simplified added mass because only the fluid coupling effect between a pair of structural nodes located at same elevation on each beam is considered, whereas the fluid couplings between any other two nodes are neglected.

Two parametric studies have been performed in which all the tank models are subjected to a 0.5-g, 10-s duration acceleration time history. The computer code, FLUSTR-ANL, was used in the calculation. In the first study, the input ground motion is applied at the base of the beams in the same direction. Thus, the vibrational motions of beams 1 and 2 are in phase. In the second study, the input motion is applied at the base of the beams in the opposite direction. The vibrational motions of the beams 1 and 2 are out-of-phase. Since the vibrational frequency of the system is very low in the out-of-phase motion, the Young's modulus of the beams is raised to 100 times of that used in the first study. The calculated seismic responses (vibrational frequency, max. displacement at beam tip, max. bending moment at beam base) of the three models in the cases of in-phase and out-of-phase motion are given in Tables 1 and 2, respectively. The seismic response of the lumped mass model for the out-of-phase motion is not shown in Table 2 because of the high natural frequency.

The results indicate that the lumped mass, simplified added mass, and coupled fluid-structure models all give close solutions in the case of in-phase structural vibrational motion. However, in the case of out-of-phase structural vibrational motion, the lumped mass model gives totally unrealistic results due to the lack of fluid coupling effect. The added mass model considers the fluid coupling effect in a simplified manner, it may result in a large difference as compared with that of the coupled fluid-structure model. Therefore, these two methods can only be used in the preliminary design stage. For the rigorous final analysis, the realistic seismic response can only be obtained with the coupled fluid-structure interaction analysis.

REFERENCES

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2. "Pool-Type LMFBR Plant 1000 MWe Phase A - Extension-1 Design," EPRI NP-882, Vol. 4, Sept. 1978.

3. *Nuclear Reactors and Earthquakes*, TID-7024, USAEC, 1963.

LIST OF FIGURES

Table 1

Comparison of Seismic Response (In-phase Motion)

	Frequency (Hz)	Tip Displacement (in.)	Base Moment (lb-in./in.)
Lumped Mass	8.75	0.23	6790
Added Mass Matrix	9.5	0.22	7230
FSI	9.0	0.30	9380

Table 2

Comparison of Seismic Response (Out-of-phase Motion)

	Frequency (Hz)	Tip Displacement (in.)	Base Moment (lb-in./in.)
Lumped Mass	87.5	-	-
Added Mass Matrix	6.33	1.59	4650000
FSI	7.66	0.64	2804000

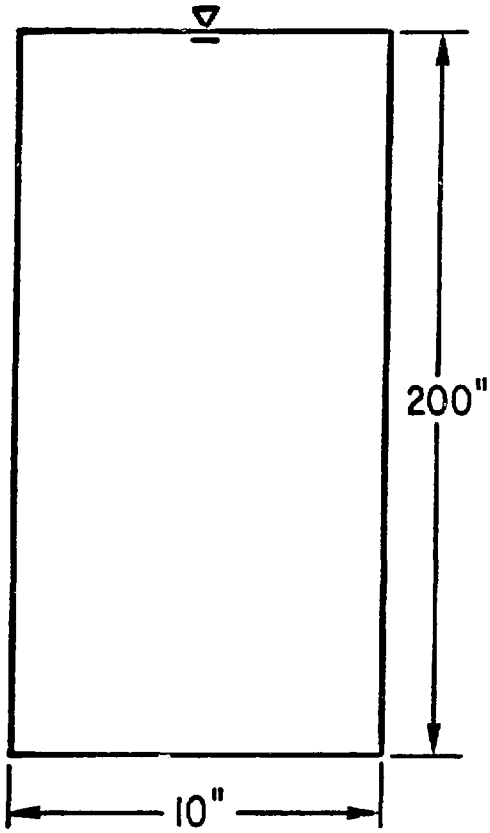

Fig. I.1. Two-dimensional Fluid-tank System

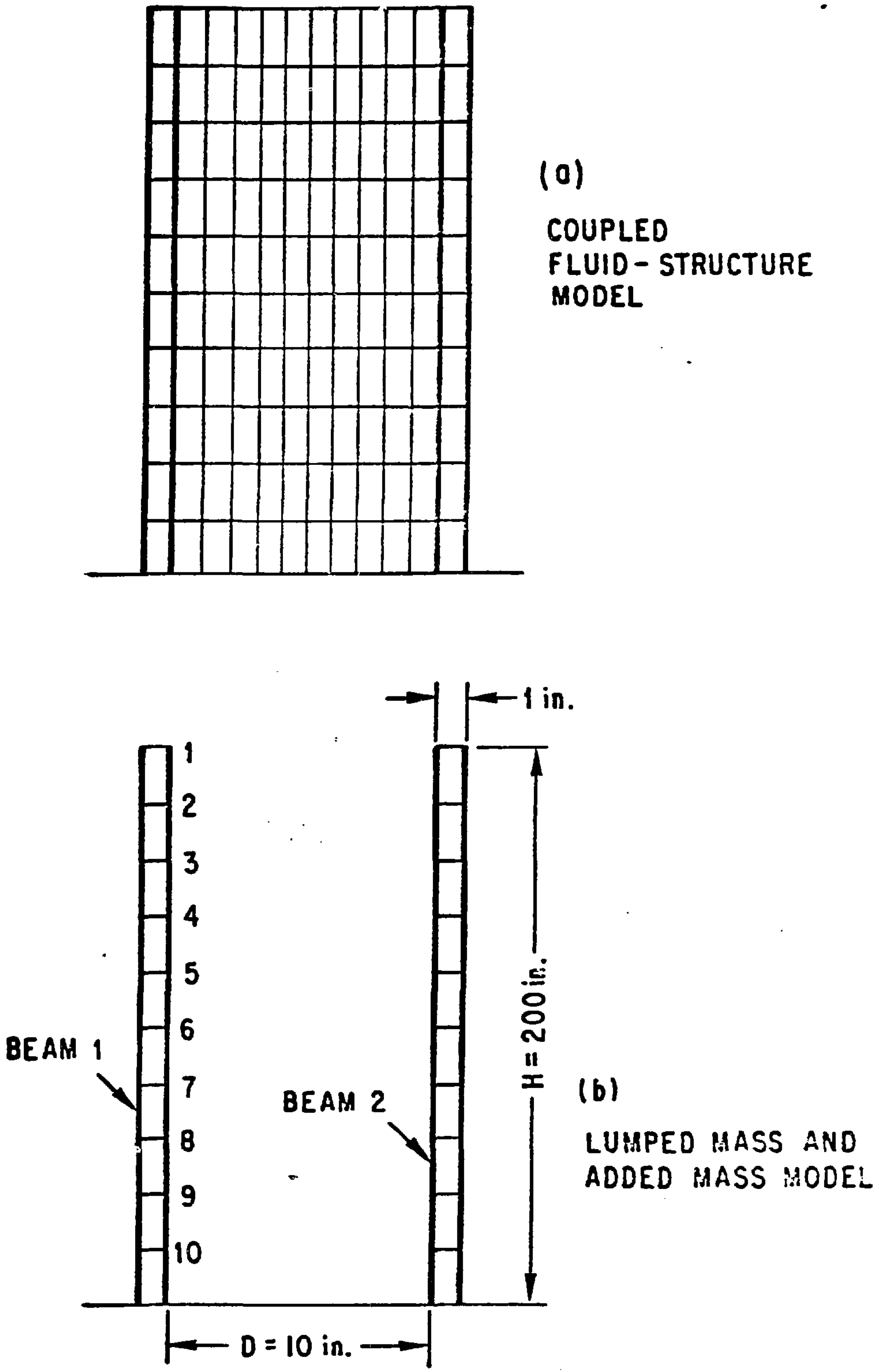

Fig. I.2. Mathematical Models.
(a) Coupled Fluid-structure Interaction Model and
(b) Lumped Mass and Added Mass Model

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