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Free Surface Hierarchical Fluid Element For The Vibration Analysis Of A Fluid In A Circular Cylindrical Rigid Tank

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Abstract— **The free vibration of liquid in a cylindrical rigid cavity is analysed by developing a hierarchical free surface finite element. It is a bi-hierarchical four-node quadrilateral element with three degrees-of-freedom (three displacements) per node. The element has the advantage that the hierarchical mode number is allowed to vary independently of direction. Free surface cavities with large aspect ratios can therefore be solved very accurately by using a higher hierarchical mode number in the longer direction than in the shorter one. Furthermore, it is possible to idealize the fluid by using only one element. The solution can therefore be obtained to any desired degree of accuracy simply by increasing the hierarchical mode number. The results are compared with other methods and show good agreement.**

Keywords—**Free surface, hierarchical fem, fluid element, free vibration, rigid cavity**

I. Introduction

In general, the fluid-structure interaction can be divided into five categories; each category requires unknowns that may not suit others. In the added mass approach, a part of the mass of the fluid is added to the structural model along the interface between the two fields. This approach neglects the compressibility of the fluid. Several methods based on the added mass approach for the analysis of the liquid storage structures were proposed (Housner, 1957, ASCE, 1986).

In the Eulerian approach (Haroun, 1983, Haroun, 1984, Veletsos, 1990, Balendra 1982, Hughes *et al*, 1981, Donea, 1982), the velocity potential, the pressure, or the velocity describe the behaviour of the fluid, while the displacements represent the movements of the structure. The solution of the coupled system can then be obtained by solving the two systems separately but by considering the effects of the interaction in an iterative way. The coupled system can also be solved as being only one system, but this leads to non-symmetrical matrix equations which require special technical solutions. Mixed Lagrangian-Eulerian methods using a velocity based formulation were also developed to solve this type of coupled systems (Hughes *et al*, 1981, Donea, 1982, Nomura & Hughes, 1992).

In the Lagrangian approach, the fluid behaviour is in general described by a displacement field (Shugar & Katona, 1975, Zienkiewicz & Bettess, 1978, Hamdi *et al*, 1978, Wilson & Khalvati, 1983, Chen & Taylor, 1990). The motion of the fluid and the structure being both described by only one displacement field, this approach has the advantage of very easily satisfying the compatibility and the equilibrium conditions along the interface. So, a fluid structure system in interaction with a complex geometry can be analysed efficiently with this method.

The liquid in this analysis is regarded as non-viscous, irrotational and incompressible. Such simplification allows displacements, pressures, or