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Thesis Outline

Transient Responses of Structures Without Fluid and Coupled with Fluid Subjected to Impact Loadings: Theoretical Analysis, Numerical Simulation, and Experimental Measurement

Ji Ming

This thesis consists of six chapters. Except for the introduction and conclusion, the outline of this thesis is described as follows:

In Chap. 2, transient responses of circular and rectangular plates subjected to a point impact load are studied. The first-order plate theory is used to derive the equations of motion by the Hamilton's principle. The out of plane dominated vibration and in-plane dominated vibration can be decoupled. The transient displacement and strain histories are obtained using the method of mode superposition. As for rectangular plates, spectral collocation method is used to solve the free vibrations of out-of-plane and in-plane modes based on the modified Mindlin-Reissner plate theory. The low density and high compliance of the Polyvinylidene Fluoride (PVDF) films make them a suitable method to measure the external dynamic force history. The force history is applied to conduct the theoretical analysis and numerical analysis. The displacement and strain histories obtained from the theoretical analysis and numerical analysis are compared with those obtained from experiments. Moreover, the effects of the thickness on the displacement and strain histories are studied.

In Chap. 3, analytical methods and a numerical method for solving free vibrations of circular and rectangular plates coupled with fluid are presented. The linear velocity potential function is used to describe the fluid motion considering a small oscillation induced by the plate vibration in fluid. The plate–fluid coupling system is constructed using the fluid pressure over the plate–fluid interface and the flexural deflection of the plate. The wet mode of the coupling system is assumed to be the superposition of the dry mode of the plate, which has been considered in few studies. An efficient method for solving the natural frequencies and mode shapes of the coupling system is proposed herein using the orthogonality of the dry modes of the plate. An efficient and flexible finite element procedure using fully vectorized codes is developed to validate the theoretical results. The four-node mixed interpolation of the tensorial component quadrilateral plate finite element (MITC4) is used to simulate the plate, whereas the eight-node acoustic pressure element is used to simulate the fluid. Parametric studies are performed to investigate the influence of geometric sizes, plate material properties, and fluid properties on the natural frequencies of the coupled system. A coupling parameter of fluid-structure interaction is proposed.

In Chap. 4, an analytical method to study the natural frequencies of free vibrations for a thick cylindrical shell filled with fluid is proposed. The Mindlin's first-order shell theory is extended to derive the equations of motion and corresponding boundary

conditions by Hamilton's principle. Linearized potential flow theory is used to derive the hydrodynamic force. Moreover, the internal fluid pressure acting on the shell wall is obtained by the assumption of a non-penetration condition. The dispersion equations are obtained under the assumption of harmonic motion. The derived shell theory is used to calculate the natural frequencies of cylindrical shells with various thicknesses and lengths, and the results are compared with the Flugge's shell theory and finite-element method (FEM). As a result, the proposed shell theory shows improved accuracy and good agreement with published experimental results.

In Chap. 5, analytical methods and a numerical method for solving transient responses of circular and rectangular thick plates coupled with fluid subjected to impact loadings are presented. The transient responses are assumed to be the superposition of wet modes of coupled system. Then, using the orthogonality of the dry out-of-plane and in-plane modes, the transient responses are solved. To validate the theoretical results, an efficient and flexible finite element procedure using the Newmark's method is proposed.