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# An Experimental Study on the Hydro-elastic Analysis of a Circular Cylindrical Shell

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## ABSTRACT

Ocean structures and vehicles are exposed to severe ocean environment conditions such as waves, winds and currents. When such ocean structures and vehicles are designed, an accurate structure analysis is required to keep the system safely. Hydro-elastic analysis is one of key issues to design such structures and vehicles. In many previous investigations, numerical analyses for hydro-elastic problem have been used. In this study, an experimental analysis is carried out and the circular cylindrical shell is considered. Dynamical characteristics for a circular cylindrical shell are identified by experimental vibration analysis in air and water. The natural frequencies and mode shapes are compared in air and water to obtain hydro-elastic effects. Some interesting results are found in the variation of natural frequencies and damping ratios of the circular cylindrical shell for different water contact depths.

KEY WORDS: Circular cylindrical shell, Modal identification, Experimental modal analysis, Hydro-elastic analysis, Natural frequency and mode

## INTRODUCTION

Ocean structures and vehicles are exposed to diverse sources of vibration, such as the vibration of the system itself or that from external load such as waves and wind. If the natural frequencies of an ocean structure and vehicles are close to the time varying external force applied to the structure or vehicle, it receives much damage due to much defection and fatigue on its structure. Research on the vibration characteristic of ocean structures and application of the knowledge to prevention of such harms are necessary.
The characteristic vibration of structures is expressed by system parameter such as natural frequency, damping ratio, mode shape, etc. These properties are decided by the quality of the material, shape, or environment conditions. Circular cylindrical shell structure is the most commonly used form in designing ocean structures and submarines. Therefore it is of great importance to investigate the vibration character of cylindrical shell structure which is in contact with water.
Many investigations have been carried out to analyze dynamic behavior of structures coupled with fluid. One of frequently employed methods for investigating the vibration character of structures is finite element method. In addition, in order to create a modeling for the studying contacting water effects on the structure, several methods such as, semi-analyical method, transfer matrix method and boundary element method are used.
Chen et al. (2003) carried out nonlinear hydro-elastic analysis of a moored box-type floating body using the linear and nonlinear three-dimensional hydro-elastic equations. Ohkusu and Namba(2004) carried out numerical analysis to predict the bending vibration of a very large floating structure of thin and elongated rectangular plate configuration like a floating airport. Askari and Daneshmand (2009) proposed finite element method using Galerkin method to analysis coupled vibration of a partially fluid-filled cylindrical container with a cylindrical internal body. Sigrist and Garreau (2007) carried out finite element method in order to produce coupled fluid-structure dynamic analysis with pressure-based formulation, using modal and spectral method. Ugurlu and Ergin (2008) investigated the effects of different end conditions on the response behavior of thin circular cylindrical shell structures fully in contact with flowing fluid using finite element and boundary element method.
Yet it is quite difficult to exactly predict the vibration character with these methods. Therefore to increase the accuracy of finite element model, some validations need to be performed through vibration experiments.
This research focuses on vibration experiments of a circular cylindrical shell structure in contact with water. By comparing the vibration characteristics of the cylindrical shell structure in air and water, it is expected to provide a proper method for interpreting vibration characteristics of ocean structures and submarines in partially contact with water.

## 2. NON-PROPORTIONAL DAMPING SYSTEM(NLLS)

The general equation of motion for a multi-degree-of-freedom (MDOF) system of N degrees of freedom with viscous damping is as follows:

$$[M]\{\ddot{x}\}+[C]\{\dot{x}\}+[K]\{x\}=\{f\} \tag{1}$$

where $[M]$, $[C]$, and $[K]$ are the $[N \times N]$ mass, damping, and stiffness matrices, and $\{x\}$ and $\{f\}$ are the $[N \times 1]$ vectors of the time-varying displacements and forces.