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Experimental Study on Deformations and Force Characteristics for Flexible Plate

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ABSTRACT

This paper presents an experimental study on deformations and force characteristics of flexible rectangular plates both in air and water. The focus is on the complex interaction between the fluid and flexible structure. The free oscillating displacement and force are measured and corresponding natural frequencies are compared. The effects of several plate coefficients are investigated: Plate thickness; Plate aspect ratio; Plate area; Plate width ratio; Bending Angle. Some experimental results are compared with numerical simulation and show a reasonable agreement. It is available to be noted that the dynamic characteristics in the water are quite different from that in the air, which indicates that more particular attentions need to be put on this subject.

KEY WORDS: Experiment; Flexible Plate; Deformation; Force Behavior; Plate Coefficient; Numerical Simulation; Fluid-Structure Interaction.

INTRODUCTION

Recent progress in watercraft design and fabrication are met by the introduction of new material, leading to more flexible structure of screw propeller of the watercrafts. The flexible propeller with composite material has significant advantages over the traditional one, such as light weight, excellent emergency ability, less noise and cavitation, low electrical and magnetic location possibilities, and the performance against the electro-chemical corrosion. The flexible rectangular plate as the simple model of propeller blades was conducted in this study. The interaction between flexible plates and fluid is a fundamental problem in fluid mechanics and plays an important role in the engineering applications, which received attention for couple of years.

Considerable effort has been made in the experimental and numerical study due to the complexity of the interaction between the flexible structure and fluid. Ihara and Watanabe (1994) studied the flow structure around the free ends of a flexible oscillating plate by flow visualization experiments. The stabilization of cantilevered flexible structures by means of an internal flowing fluid was investigated (Sugiyama and Katayama, 1996). A computational model was applied in the study of the hydroelastic response of simple panels and compliant walls to a uniform study (Lucey and Cafolla, 1997). A numerical approach was developed in the calculation of the time-dependent fluid-structure problem for membrane and thin shell structures (Gluck and Breuer, 2003). The linear vibration analysis of cantilever plates partially submerged in fluid was numerically study (Ergin and Ugurlu, 2003). Balint and Lucey (2005) investigated the instability of a flexible cantilevered plate in viscous channel flow with solving the Navier –Stokes equations for flow and the dynamics of the plate motion solved using finite-differences.

Fluid-structure interaction (FSI) of flexible body is one of the most complex and difficult applications currently being studied. For a coupled fluid-structure system, the deformation of the structure influences the fluid domain, and the pressure generated by the fluid will force on the structure accordingly. Numerical modeling of flexible structures is relatively new and has only been started in the last decade. A technique known as the arbitrary Lagrangian–Eulerian (ALE) description (Donea1 and Huerta, 2004) which combines the best features of both the Lagrangian and Eulerian approaches, is applied in FSI problem to overcome the drawbacks of each purely description. The hybrid Cartesian/immersed boundary (HCIB) method (Gilmanov and Sotiropoulos, 2005) using boundary conditions at the grid nodes closest to the solid boundary, is recently developed for the FSI problem for flexible body. It has been applied in the computation of the flexible cantilever successfully (Shin, 2006).

The FSI problem is also encountered with the rapid progress of the commercial software. ADINA combined the structure and fluid dynamic equations of motion in a single uniform system using the FCBI (Flow-Condition-Based Interpolation) to satisfy the displacement coherence and force equilibrium on the interface. In most complicated cases a single simulation system cannot provide all necessary features. Coupling of the most suitable codes for each necessary discipline will enable more flexibility and simulation quality. MpCCI (Mesh-based parallel Code Coupling Interface) is a software environment which enables the exchange of data between the meshes of two or more simulation codes in the coupling region. It performs an interpolation and allows the exchange of nearly any kind of data between the coupled CFD and FEM codes. Although the numerical simulation with