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An Experimental and Numerical Study on Vortex-induced Vibrations of a Hanging Flexible Riser with Its Top in Irregular Motion

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A numerical scheme is developed to simulate the time series of 3-dimensional dynamics of a flexible riser moving irregularly at its top end. To validate the accuracy of this numerical scheme, some cases were compared with the experimental results. In experiments, the top end of a hanging riser model was forced to oscillate irregularly in surge motion in still water. The irregular motion of the top end was defined by a narrow-banded wave spectrum. Good agreement between the amplitudes and frequencies of vortex-induced vibrations are seen in those comparisons.

INTRODUCTION

Marine risers are used for many purposes in ocean activities. They have very long lengths compared with their cross-section area, and they show very flexible behavior. These marine risers are always exposed to many external forces, such as gravity, fluid forces and reaction force from the floating structure.

Many researchers have carried out experimental and numerical studies on the vortex-induced vibrations (VIV) of cylindrical marine structures. One well-known textbook is that by Blevins (1990); the experimental VIV model (Iwan et al., 1974) was introduced in this book. Bishop et al. (1964) first proposed such an experimental VIV model.

As computer performance has progressed, numerical simulation for VIV has been carried out. Etienne et al. (2001) and Willden et al. (2001) recently reported a numerical scheme combined with the fluid force and finite element method (FEM). Julio et al. (2004) calculated such fluid force by the discrete vortex method (DVM).

Numerous experimental approaches have used full- or model-scale risers. For example, Vandiver (2000) analyzed the dynamics of full-scale drilling risers. In addition, there are other useful experimental studies of the VIV of marine risers, such as those by Grant et al. (2000), Bando et al. (2001) and Hong et al. (2002).

There are few numerical or experimental studies of the hanging riser moving irregularly at its top end. If the top end of the hanging riser moves irregularly, the vortices would be shed irregularly according to the main motion of the riser, and motions are always transient. Thus, it would be hard for the lock-in phenomenon to occur, and the VIV would be more complex.

In this research, we developed a scheme of the time series simulation of the VIV of the hanging flexible riser. We also carried out some irregular forced oscillating experiments. In the experiments, the top end of the riser model was oscillated irregularly in a horizontal plane (X direction). This irregular motion represents the surging motion of the floating structure caused by ocean waves. For the wave data of irregular surging motion, we used an International Ship and Offshore Structures Congress (I.S.S.C) wave spectrum, which is defined as having significant wave height (Hw) and mean period (Tw). Experimental conditions were determined as combinations of the Hw and Tw. The resulting 3-dimensional motion of the model was measured with CCD cameras, and the results were analyzed using a motion picture analysis method.

Finally, by comparing the numerical and experimental results, the accuracy of this numerical scheme was validated.

Model length (m)		6.5
Outer diameter (mm)		22.5
Inner diameter (mm)		12.7
Mass per length (kg/m)		0.4
Young's Modulus (MPa)		8.847
Bottom weight in water (N)		3.489
Natural frequencies ω of model (rad/s)	1st	0.571
	2nd	1.308
	3rd	2.207
	4th	2.732

Table 1 Characteristics of riser model

MODEL EXPERIMENT

Model Characteristics and Experimental Setup

A flexible riser model made of polyethylene and Teflon (PTFE) was used in this experiment. Table 1 shows the model characteristics.

The natural frequencies of the model shown were calculated analytically by solving the approximate free vibration equation of this model. The free vibration equation assumes that the bending stiffness would be small enough to neglect, and that the tension effect would be dominant (Park et al., 2002).

This experiment was carried out in the towing tank (65 m long × 5 m broad × 7 m long) at Kyushu University's Research Institute for Applied Mechanics. The top end of the model was connected to a parallel mechanism-type forced oscillator by using a universal joint (Fig. 1).

Thus, the boundary condition at the top end of the model was simply supported. An additional weight was attached to the bot-

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