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Development of New Device for Reduction of Fluctuating Lift on Riser Pipe

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This paper describes a new technology for suppressing vortex-induced vibration. Based on the idea of tubercles at the leading edge of a whale flipper that improve stall characteristics, a new device for reduction of fluctuating lift acting on a riser pipe is developed. As a result, the fluctuating lift acting on the stationary cylinder with the tubercles is reduced by 89% from the normal cylinder. In addition, at a mass damping parameter of 1.3, the maximum amplitude of the oscillating cylinder with the tubercles is one-sixth as much as that of the normal cylinder.

INTRODUCTION

A cylinder like a riser pipe in ocean current has a problem of vortex-induced vibration (VIV). Studies with hydrodynamically controlled devices for suppressing VIV have been conducted. Various suppression devices, helical fins (Chung and Whitney, 1993), shroud (Wong and Kokkalis, 1982), fairing (Allen, 2003), and changes to pipe geometry (Owen and Bearman, 2001) have been developed.

Helical fins and fairing are used commonly as the existing technology for suppressing VIV. Although both devices have a good effect on the suppression of VIV, they have some technical issues. The drag acting on helical fins is larger than that on the normal cylinder. The size of fairing is nearly twice as large as that of the normal cylinder. Furthermore, additional operation for mounting and dismounting the vibration-controlled devices is necessary. Therefore, a device that offers less resistance and is more compact, with no need for extra operation, is desired.

On the other hand, studies on the mechanism of improving stall characteristics of tubercles at the leading edge of a whale flipper have been conducted (Miklosovic et al., 2004; Arai et al., 2010; Weber et al., 2011). These studies show that longitudinal vortex shedding downstream of tubercles on a whale flipper suppresses flow separation. Therefore, after objects like tubercles of a whale flipper are attached at the leading edge of a cylinder, it is likely that longitudinal vortex shedding downstream of tubercles will suppress Kármán vortex shedding.

First in this study, for riser pipes in unidirectional flow, the shape of tubercles that are effective in the reduction of fluctuating lift is developed by using computational fluid dynamics (CFD). Second, for riser pipes in multidirectional flows like ocean currents and tidal currents, hydrodynamic forces acting on a cylinder with tubercles arranged in a spiral are investigated by using CFD and a tow tank test. Finally, a free vibration test in a wind tunnel is conducted to verify the effect on suppressing VIV.

MEANS OF STUDY

Basic, characteristic VIV at subcritical values of the Reynolds number, where vortex shedding is strong and periodic, is researched by CFD, tow tank test, and wind tunnel test (WTT).

Computational Fluid Dynamics

The commercial software Fluent (ANSYS, 2012) is used to investigate hydrodynamic forces and to optimize the shape of tubercles. Table 1 shows calculation conditions. Large-eddy simulation is used as a turbulence model, and grid resolution on a surface, $y+$, is less than 0.5 in order to simulate unsteady flow around a riser pipe due to Kármán vortex shedding.

Figure 1 shows an analysis domain. The analysis domains in the direction of the cylinder axis are from πD long to $7D$ long, depending on the unit of length of the tubercles arranged in a spiral, where D is the diameter of a cylinder. The boundary condition

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KEY WORDS: Vortex-induced vibration, vibration control device, riser pipe, CFD, tow tank test, wind tunnel test.