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Vortex-Excited Vibration of a Vertical Circular Cylinder in Waves

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ABSTRACT

This study deals with some of the nonlinear phenomena of the vortex-excited vibration of a circular cylinder in waves. Laboratory experiments have been performed to study the dynamic transverse response of a vertical circular cylinder in regular waves. The test cylinder was pivoted at its base and supported flexibly by springs at its top. The movement of the test cylinder in the inline direction was restricted. The most remarkable result is the appearance of two types of peak in the amplitude of the vortex-excited vibration of the cylinder produced by perfect resonance coupled with waves and by vortex coupling. In the case of steady flow, perfect resonance appears in the locked-in range, but in waves, it appears only close to ratios of wave frequency f_w to the natural frequency f_{nw} of the cylinder in still water in the sequence of f_w/f_{nw} = 1/2, 1/3, 1/4,…; elsewhere vortex coupling may occur for light damping in which the oscillation frequency is not a simple multiple of wave frequency.

INTRODUCTION

The dynamic response of offshore structures to wave forces is one of the most important factors in their design. Many instances have been reported where the failure of a structure is believed to have been caused by its response to frequencies of wave forces acting on it. Wave forces acting on a vertical cylinder are usually resolved into two components, inline force and a lift force. The inline force acting in the direction of wave propagation is usually expressed by using the Morison equation, and acts predominantly at a frequency equal to the wave frequency f_w. The lift force acting at right angles to the wave propagation is caused by vortex shedding and its predominant frequency is a multiple of that of inline force. Therefore, the lift force may give rise to a significant dynamic response in the cylinder.

A great number of experiments have been done in order to study the phenomenon of vortex-excited vibration of a cylinder in steady flow. Summaries have been made by Blevins (1977), Sarpkaya (1979) and Bearman (1984). In this case, if the vortex shedding frequency approaches the natural frequency of a lightly damped cylinder, the vibration of the cylinder becomes larger, and this large vibration can drive the eddies to be shed with a frequency ranging between the natural frequency of the cylinder and the Strouhal frequency. This phenomenon is usually called lock-in between the frequency of vortex shedding and the frequency of the vibrating cylinder. Under lock-in conditions, large resonant vibration occurs and the lift forces are amplified both by the increase of vortex strength and by the improved correlation in the phase of vortex shedding along the cylinder axis.

A similar phenomenon may occur under certain conditions, if an elastically mounted vertical cylinder is placed in waves. However, this has not been sufficiently understood and relatively little work has been carried out into this interesting problem in planar oscillating flow and in waves. This is mainly due to the complexity of the phenomenon, because the incident flow acting on a vertical cylinder in waves is oscillatory, varies with depth and possesses a vertical component. A comprehensive summary has been made by Sumer and Fredsøe (1994).

The work presented herein is an experimental investigation into the nonlinear vortex-excited vibration of a vertical circular cylinder in regular waves. Emphasis is placed on the influence of the damping factor and Keulegan Carpenter number KC to the relationship between the transverse response and the ratio of wave

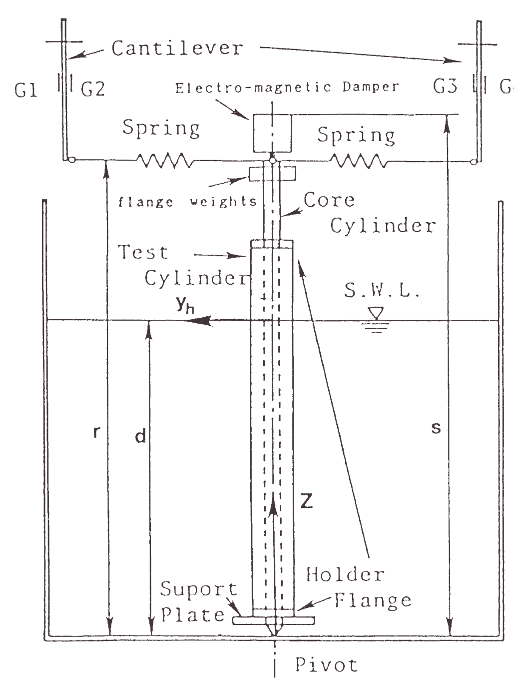

Fig. 1 General arrangement of test cylinder

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