International Journal of Offshore and Polar Engineering
Vol. 11, No. 2, June 2001 (ISSN 1053-5381)

In-Line Force from Combined Wave and Current Flow on Oscillating Cylinders

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ABSTRACT

The flow pattern and force coefficients for oscillating cylinders are different from those for fixed structures. Experiments have been carried out to study wave-current-structure interactions by oscillating a vertical cylinder in the cross-flow and in-line direction with a steady flow and/or waves regular and irregular. An important goal of the work has been to develop a generalized approach for estimating the hydrodynamic interaction of slender cylinders in a wide variety of flow conditions and to determine the necessary force coefficients for such complicated flow conditions. The present paper deals with results of cylinder oscillations parallel to waves and current and concentrates on the in-line force components. Evidence has been produced suggesting that both the relative velocity extension of the Morison equation and a linear version of this model are suitable models to estimate the in-line hydrodynamic forces in the flow condition considered. It has been found that the linear form of the "generalized" Morison equation based on the relative velocity approach gives the same or even better quality of fit as the quadratic form, if the associated value of the linearized drag coefficient is used. Extensive analysis of the force coefficients of the relative velocity model has been carried out to seek a good correlation between the drag and inertia coefficients (C_{Dr} and C_{Mr}) on the one hand and the relevant nondimensional parameters on the other. The results of this investigation have revealed no single parameter with which the drag and inertia coefficients may be correlated without the need for other parameters. However, the force coefficients correlate better with some parameters than with others. The ratio between total oscillatory velocity ($u_m + \dot{x}_m$) and the steady velocity (V) is a significant parameter for the combined flow field of an oscillating cylinder in waves and current.

INTRODUCTION

Slender cylinders are crucial elements of many types of offshore structures (fixed, compliant and floating) as well as important independent parts of various offshore systems (e.g. risers, cables, umbilicals and ropes). Such slender cylindrical members experience excitation as well as reaction forces caused by the movement of the structure as a whole, which results from the action of hydrodynamic forces due to waves and current. These forces obviously depend on the fluid properties and flow conditions in the ambient environment, as well as on the geometry, orientation and motion of the cylinder itself. The excitation and reaction forces constitute complex nonlinear hydrodynamic phenomena. However, the fluid-structure interaction for such structures has generally been studied either in a steady flow (mostly), or in waves (barely), as reviewed by Chakrabarti (1987), Blevins (1990), and Bearman et. al (1992).

There have been a number of studies on superimposed oscillatory and mean flow past a stationary cylinder, or oscillating cylinder in an incident flow. For example, Kato et al. (1983) and Low et al. (1989) studied hydrodynamic forces on cylinders oscillating in-line with a uniform flow. Iwagaki and Asano (1984) examined the hydrodynamic force acting on a fixed circular cylinder due to combined wave/current loading and introduced 2 new Keulegan Carpenter numbers as parameters for the hydrodynamic force coefficients. Also, Kan et al. (1992) have investigated the in-line force on a vertical circular cylinder and analysed hydrodynamic coefficients C_D, C_M in a wave-current co-existing field. Through analysis and comparison of the experimental results, they have indicated that if the Keulegan-Carpenter number for various environmental conditions is the same, then the corresponding values of C_D, C_M should be approximately the same, no matter whether in a wave-only field, in a wave-current coexisting field, under regular or irregular waves. Malenica et al. (1995) have considered the problem of a vertical circular cylinder submitted to both regular waves and moderate current in water of finite depth. Recently, wave-current forces on a rectangular cylinder have been studied by Vengatesan et al. (1999).

A number of investigators have studied wave forces on oscillating cylinders, e.g., Verley and Johns (1982), Koteryama and Nakamure (1986). Lipsett and Williamson (1994) have studied the response of a flexibly mounted rigid cylinder in an oscillatory flow.

A more complete experiment including more general motions (i.e., wave, current and cylinder motion) has been carried out in the present work.

Tests have been carried out to study flow-structure interaction experimentally by oscillating a vertical cylinder in the cross-flow and in-line direction together with a steady flow and/or waves, regular and irregular. The purpose was to obtain an unbiased set of laboratory measurements of the total interaction between the hydrodynamics (wave and current) on the one hand, and the moving cylinder on the other. Details of the experimental program may be found in Shafieefar (1995).

This paper considers only the hydrodynamic interaction with

Received January 4, 2000; revised manuscript received by the editors December 28, 2000. The original version was submitted directly to the Journal.
KEY WORDS: Combined waves and currents, oscillating cylinder, in-line force.