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Dynamically Responding Vertical Cylinders in the Morison Regime — The Influence of Structural Damping

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ABSTRACT

An experimental investigation of the Morison force coefficients and the effect of structural damping on the forcing of dynamically responding vertical cylinders has been conducted in order to evaluate the suitability of existing mathematical models. It was observed that useful values of the Morison force coefficients C_M and C_D could be obtained from measured cylinder restraint forces by both a constant-valued least squares method and a nonlinear systems analysis approach with little practical differences. Force coefficients C'_M and C'_D were obtained experimentally from pluck tests and the values of C'_M were found to agree closely with classical predictions and those from radiation damping considerations, whereas C'_D appeared to be greatly dependent upon the viscosity-frequency parameter β. It was found that the selection of C_D is critical to the prediction of hydrodynamic damping, and that for cylinders operating in the inertia dominant range (KC < 5) the drag dependent hydrodynamic damping mechanism is *significant* despite the relatively minor role drag force would have in the actual hydrodynamic forcing process itself.

INTRODUCTION

An offshore structure is often found to be primarily excited in its fundamental mode of vibration by the prevalent hydrodynamic loading. Consequently it is observed to respond principally in the alongwave direction so that a simplified modelling of its in-line response $x_0(t)$ at the mean water level (MWL) can be expressed as:

$$\ddot{x}_0 + 2\omega_0\zeta_s\dot{x}_0 + \omega_0^2 x_0 = \frac{F'_0(t)}{m_0 + m_a} \tag{1}$$

where ω_0 is the structure's natural circular frequency, ζ_s is the critical damping ratio for the structure, m_0 is the effective mass, m_a is the added mass; and $F'_0(t)$ is a version of the equivalent hydrodynamic forcing at the MWL, which for a simple single bottom-mounted vertical cylinder is given by:

$$F'_0(t) = \int_{-h}^{0} f(z,t)\psi(z)dz \tag{2}$$

where $f(z,t)$ is the alongwave force per unit length at level z associated with all possible sources of hydrodynamic loading (wave radiation, Morison loading, lift forces, etc.) that acts on the structure located in depth of water, and h and $\psi(z)$ are the mode shape of the structure.

This paper will discuss a damping model for such a structure, which includes radiation, hydrodynamic and structural damping and shows the relationship between the hydrodynamic and structural contributions. The model was tested with an experimental programme that included pluck tests in air and still water, rigid cylinder tests to obtain the Morison force coefficients and compliant cylinder tests to provide data for the damping model.

MORISON MODEL

Hydrodynamic Damping and Morison Force Coefficients

A somewhat simplified model for an offshore structure would be that of a single vertical surface-piercing cylinder of diameter D as depicted in Fig. 1, for which the mode shape is simply given by a straight line. A model for the total level of damping in the response of such a compliant bottom-pivoted cylinder in unidirectional sea states ζ_t has been suggested (Yang, 1990) to take the form:

$$\zeta_t = \zeta_s + \zeta_a + \zeta_r + \zeta_H \tag{3}$$

where ζ_r represents radiation damping and ζ_H hydrodynamic damping due to drag effects, and where ζ_a accounts for additional damping that may be present and not accounted for elsewhere (e.g. damping associated with the structure restraint/support con-

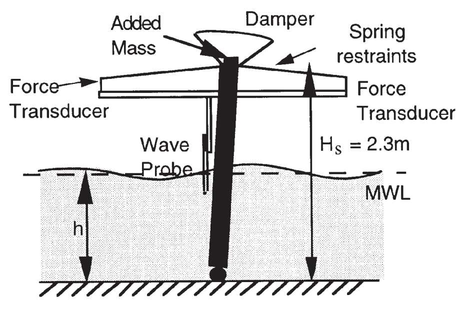

Fig. 1 Schematic of test cylinder in wave tank

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