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Wave-Current and Fluid-Structure Interaction Effects on the Stochastic Analysis of Offshore Structures

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ABSTRACT

This paper presents a stochastic analysis method for deepwater offshore structures under wave-current and structure-fluid interactions. The spectral modelling of random waves riding on a current is first explained. Then, a procedure is described to calculate relative water velocities, wave forces, hydrodynamic damping and added masses. To apply a spectral method to the analysis, an appropriate linearization technique for the nonlinear drag force term of Morison's equation is introduced. This technique uses an equivalent second-moment criterion and the relative water velocity concept. A response analysis procedure which includes both the quasi-static and dynamic contributions is outlined. Since the relative water velocity statistics are used in the analysis, the calculation is carried out by an iterative algorithm. It is observed in general that both the current and the fluid-structure interaction have a profound influence on a response spectrum of the structure.

INTRODUCTION

Design of offshore structures under wave-current action in deep ocean environments can properly be carried out by including the effects of wave-current and fluid-structure interactions in the analysis. Since the loading process in an ocean environment is stochastic, a spectral analysis procedure is generally applied to determine the spectrum of a structural response quantity. In such an analysis, the existence of current is reflected in the response spectrum in two ways:

a) It influences the random wave field by changing the wave number, wave frequency and wave amplitude so that the sea spectrum is also changed.

b) The drag force term is dependent on the current velocity and the linearization coefficient of this term is strongly affected by the current.

In addition to these items, the current also produces non-zero mean response values. In general, wave-current interaction is very complicated. Under certain conditions only a spectral description of a sea state in a wave-current field can be formulated in terms of sea spectra in a quiescent condition.

Structures in a deepwater environment are relatively flexible and dynamic sensitive. Their flexibility is taken into account in the force calculation by using the relative water velocity in Morison's equation. Then, a stochastic linearization technique (Atalik and Utku, 1976) is employed to linearize the nonlinear drag force term, from which the linearization coefficient will be obtained as a function of both the water and structural velocity variances. In this case, the fluid-structure interaction affects not only the applied loadings but also the structural transfer function through the damping term. Consequently, a response spectrum can be considerably influenced. In the past, efforts had been focused on the linearization of the drag force term under wave-current action (Leira, 1987; Gudmestad and Connor, 1983; and Langley, 1984), rather than concentrating on a complete spectral response analysis. For stiff structures, the effect of current on structural response results was also studied (Gomathinayagam et al., 1990) by neglecting the fluid-structure interaction. However, for flexible structures, such an interaction can no longer be neglected since it may considerably affect response values. For stiff structures, an advanced spectral analysis method was presented (Karadeniz, 1989a, 1989b). This paper outlines the extension of this method for flexible structures, including the effects of wave-current and fluid-structure interactions. But, first, a procedure for modelling of random waves on a current is summarized since it constitutes the basis of the analysis.

RANDOM SEA IN WAVE-CURRENT AREA

The wave-current interaction problem has been discussed extensively (Jonsson et al., 1970; Peregrine, 1976; Thomas, 1981; and Baddour and Song, 1990) and therefore does not form the major subject of this paper. Only the statements needed in the spectral response calculation will be presented herein. As mentioned in the introduction, current has a considerable influence on the sea spectrum which can be obtained under certain conditions. The sea spectrum in a wave-current environment depends on whether the wave is generated on the current (homogeneous case) or generated first in quiescent (zero-current) conditions and then on the current after propagation (inhomogeneous case). In both cases, the fundamental assumption is made that the current is uniform and does not change direction along the water depth and

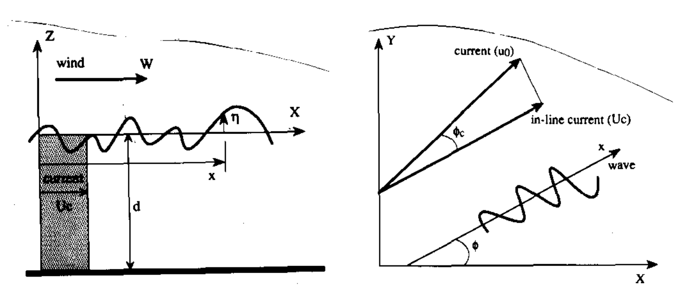

Fig. 1 Definition of wave-current field

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KEY WORDS: Offshore structure, wave-current interaction, fluid-structure interaction, hydrodynamic damping, added mass, spectral analysis.