Dynamic Analysis of Tower Buoy in Irregular Waves

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ABSTRACT

The dynamic behaviour of a tower buoy as a slender offshore structure in irregular waves is considered as a nonlinear random hydroelastic problem. It is formulated analytically by the differential equation of tower motion as a beam. Wave load is specified by a modified Morison equation. Numerical procedure is formulated by the finite element method. Time integration is performed in the case of large and small amplitude motion. The latter task is also linearized and solved in the frequency domain. Correlation analysis is performed and nonlinear phenomena are discussed.

KEY WORDS: Tower buoy, wave load, hydroelasticity

INTRODUCTION

A tower buoy is a specific slender structure used as a rigid girder of a flexible pipe that is used for oil transport from an installation placed at the sea bottom to a ship or platform on the sea surface. The buoy structure consists of an open flexible pipe and a closed cylinder at the top, Fig.1. The tower buoy is simply supported at the sea bottom. The closed cylinder balances a great part of the buoy weight and insures its stability (Bishop and Price, 1979; Zienkiewicz, Lewis and Stagg, 1978).

The tower buoy is loaded by water current and wave forces (Brebbia and Walker, 1979; Sarpkaya and Isaacson, 1981). In the case of regular and irregular waves the buoy motion is a nonlinear deterministic and random process respectively. It is solved by time integration. The problem may be linearized and an approximate solution in frequency domain may be obtained.

This article deals with the dynamic behaviour of a tower buoy as an elastic structure in irregular waves. This nonlinear hydroelastic problem is formulated analytically by the governing differential equation of motion for the tower as a beam. Sea state is described by JONSWAP and Pierson-Moskowitz wave energy spectra (Madsen, Krenk and Lind, 1986). Wave load is given by a modified Morison equation (Liaw, Shankar and Chua, 1989 and 1992). The finite element method is applied (Zienkiewicz, 1971; Bathe, 1990). The matrix differential equation is reduced to modal differential equations. Time integration procedure is described in the case of large and small amplitude motion. Furthermore, the small amplitude problem is linearized and solved in the frequency domain. The response spectra of top deflection and support reaction are compared, and nonlinear phenomena are analysed (Parunov, 1996).

The reported analysis is an extension of the paper (Senjanović and Parunov, 1997), in which the motion of the tower buoy in regular waves is considered. The investigation was motivated by the fact that the second and third order superharmonics in the nonlinear response have occurred as a result of large displacements and nonlinear drag force respectively.

![Fig.1 Tower buoy](image1)

![Fig.2 Trajectory of fluid particle](image2)

WAVE LOAD

Irregular wave

Irregular wave is an idealization of random wave sample in rough sea (Chakrabarti, 1994). It may be presented as a sum of