Proceedings of the Eighth (1998) International Offshore and Polar Engineering Conference
Montréal, Canada, May 24-29, 1998

ISBN 1-880653-34-6 (Set); ISBN 1-880653-37-0 (Vol. III)

Wave Forces on Large Cylinders in Multidirectional Irregular Waves

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ABSTRACT

Laboratory experiments were conducted in a three dimensional wave basin with a multi-directional wave maker to measure the diffracted waves due to a cylinder array and the wave forces acting on cylinders in a directional sea condition. An array of two or three cylinders was installed in the wave basin.

The wave height between the cylinders is significantly affected by the cylinder's spacing and it increases as the cylinders get closer. The interaction between the diffracted waves from the cylinders, however, becomes less appreciable when the spacing between cylinders is larger than twice of the cylinder diameter.

The wave forces in the principal direction for a two-cylinder array are almost the same as those acting on an isolated cylinder when the spacing is twice of the diameter. However, they tend to increase with decreasing distance between the cylinders and clear differences are confirmed in a comparison with the isolated cylinder case. It has also been found that the spreading of directions of the incoming waves reduces the wave force in the principal direction for an isolated cylinder. In case of a cylinder array, however, it has been observed that the spreading parameter has a less effect on the wave force. This indicates that the design based on unidirectional waves cannot always give a conservative estimation.

KEY WORDS: Wave diffraction, diffraction force, cylinder array, directional sea

INTRODUCTION

The directionality of incoming waves becomes important as the water depth of a construction site of offshore structures is increasing, because the effect of wave refraction becomes less than the shallow water region. Thus, it should be considered properly in the design of them. In case of an isolated circular cylinder, the superposition of the linear solutions obtained by MacCamy and Fuchs (1954) is applicable when the incident wave has a small steepness. Ikegaya et al. (1994) measured the pressures at certain locations on an isolated cylinder surface and effectiveness of this technique was examined. The nonlinear effects, however, are expected to become more evident as the design wave height increases. They may have a pronounced impact on the wave forces as well as on the wave field around it.

The nonlinear effects in the wave diffraction due to an isolated cylinder are discussed by many researchers (e.g., Kriebel (1990), Chau&Taylor (1992), Sanada et al. (1996)), and important features were pointed out. These analyses were carried out for a regular wave field. In a directional sea condition, the nonlinear solution of diffracted waves was derived for an isolated cylindrical structure (Mizutani et al, 1997). This solution is applicable only for an isolated cylinder. In case of a cylinder array, Mizutani et al. (1994) carried out hydraulic experiments and numerical simulations based on the linear wave theory. They pointed out that the dimensionless wave force is governed not only by the diffraction parameter but also by the spacing of the cylinders and direction of incident waves, which coincides the calculation results based on the linear wave theory (e.g., Isaacson, 1978). In the directional sea condition, there are so many waves propagating to different directions, which may lead to quite different wave force characteristics from the regular wave field. Unfortunately, there is no available information on the wave diffraction due to a structure consisting of a finite number of cylinders in a directional sea condition. This study is intended to discuss experimentally the wave diffraction due to a cylinder array and the resultant wave forces on each cylinder of an array.

LABORATORY EXPERIMENT

Experimental Setup and Procedure

Laboratory experiments were carried out using a wave basin (30m in length, 23m in width and 1.2m in depth) at the Electric Power Research & Development Center, Chubu Electric Power Co.,Inc. As shown in Fig.1, a multi-directional wave maker consisting of 42 wave paddles with a width of 0.5m is installed. The cylinder model has a diameter (D) of 60cm and a height of 1m to avoid wave overtopping. Two-cylinder array and three-cylinder array have been considered in this study. For comparison, experiments for the case of an isolated cylinder have been also conducted. These structures have been