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Effect of Fluid Force Acting on the Colliding Body upon the Elastic-Plastic Response of an Offshore Structure

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ABSTRACT

When an offshore structure is damaged through a collision with a ship or an iceberg, a certain influence from the fluid force acting on the colliding body is expected. However, reports on this subject are limited in number and the information available is rather fragmentary. The characteristics of the phenomenon depend on the relative duration time of collision. In general, the duration time is determined not only by the mechanical properties of the collided structure, such as its stiffness and strength, but also by the mass of the colliding body. To obtain a general view of the phenomenon when the behaviors of the structures are elastic and elastic-plastic, the authors studied the effect of the fluid force under collision through experiments and numerical analyses. It is shown that the degree of the effect of the fluid force can be classified by parameters that are related to the relative duration time of the collision. Further, the degree of the effect is shown to be predicted using the proposed parameters.

INTRODUCTION

Offshore structures operating under severe conditions are subject to collisions with various objects, such as supply boats, drifting icebergs and dropped objects from the platform. Therefore, it is necessary, in the design process, to estimate the damage and the residual strength of the offshore structure after damage caused by the possible collisions (Ellinas and Valsgard, 1985). In general, the structural types of offshore structures are quite diverse, such as jackets, jack-ups and semisubmersibles. Consequently, their stiffness and strength vary from one platform to another. In addition, the size of the colliding body widely varies from a small dropped object to a huge iceberg. It may be expected that depending on the combination of the type of the structure and the size of the colliding body, the collision phenomenon changes its characteristics. Thus, it is necessary to characterize the collision problem based on rational parameters to understand the fundamental features of a collision phenomenon that involves wide variations.

The authors conducted a series of experimental and numerical studies on collision responses of the collided member alone and also of the whole structure. Based on these, a couple of parameters that characterize the phenomena were proposed, and collision problems are classified using these parameters (Ueda et al., 1986, 1987, 1989, 1990). However, in these studies, the colliding body was treated as a simple rigid body, and the fluid force acting on the floating body such as the supply boat was neglected. In general, the fluid force acting on the floating body has been considered through the added mass. As pointed out by Motora (1971) and Martin (1981), such added mass changes with the time during the collision process, and it cannot be represented by a constant value. Thus, Blok et al. (1979, 1983) proposed two different equivalent added masses defined based on the momentum and energy. Further, they investigated the effect of the stiffness of the collided structure on the added mass. The behavior of fluid around the colliding body depends not only on the stiffness of the structure but also on its strength and the shape, mass and velocity of the colliding floating body. However, reports providing such information are quite limited.

To clarify the effects of the mechanical properties of the collided structure and the mass of the colliding body and its shape, the authors investigated the elastic and elastic-plastic responses under collision by experiments and numerical analyses. Based on these studies, dimensionless parameters, which correspond to the relative length of the duration time of collision, are proposed. Further, phenomena are classified using these parameters.

DIMENSIONLESS PARAMETERS

The fluid force acting on the colliding floating body is expected to be dependent on the stiffness and the strength of the collided structure and also on the shape and mass of the colliding body. To classify the phenomena on an unified base, dimensionless parameters are introduced. The procedure to derive these parameters and the similarity rules have been reported by the authors (1990). Only the physical meanings of these parameters are discussed in this paper.

As shown by Fig. 1, the behavior of the fluid during the collision is characterized by the ratio ξ between the representative dimension of the colliding body L and the length of the representative wave generated by collision λ. Thus, the parameter can be defined as:

$$\xi = L/\lambda \tag{1}$$

If the depth of the sea is assumed to be infinite and the

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KEY WORDS: Collision, offshore structures, fluid force, added mass, elastic-plastic response, classification, dimensionless parameter.