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Experimental investigation of slamming impact acted on flat bottom bodies and cumulative damage

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Abstract

Most offshore structures including offshore wind turbines, ships, etc. suffer from the impulsive pressure loads due to slamming phenomena in rough waves. The effects of elasticity & plasticity on such slamming loads are investigated through wet free drop test results of several steel unstiffened flat bottom bodies in the rectangular water tank. Also, their cumulative deformations by consecutively repetitive free drops from 1000 mm to 2000 mm in height are measured.

Keywords: Slamming phenomena; Impulsive pressure load; Wet free drop test; Flat bottom body; Cumulative damage

1. Introduction

When most offshore structures including offshore wind turbines and ships are operated in rough seas, the structural damages due to slamming phenomena are frequently reported (Yamamoto et al., 1985; JAIC 1997; Buchner and Voogt, 2004; MAIB 2008). Recently, Floating Offshore Wind Turbines (FOWTs) have been installed in deep water. Severe impulse loadings due to slamming can act on FOWTs and their structural strength may deteriorate due to consecutive slamming loadings. Since Chuang (1966, 1970) performed an experimental investigation of rigid flat-bottom body slamming and a series of wet free drop test using rectangular elastic plates, respectively, experimental studies on slamming impact have been made to estimate exact values of peak pressure. The steel plate thickness in the ship hull scantling step is determined under the assumption that the quasi-statically equivalent design load is applied based on the measured slamming pressure peak (Chuang, 1970). Recently, Sayeed et al. (2010) and Lewis et al. (2010) carried out wet free drop tests of wedges with 10° dead-rise and 25° dead-rise, respectively. Even if the wet free drop tests for the representation of slamming phenomena are carried out in the same condition, the measured peak pressures can be different due to the uncertainty. Also, the cumulative deformation of the flat bottom plate due to consecutively repetitive wet free drops has not been reported in the open literature.

In this study, wet free drop tests are repeatedly performed using steel wedges with unstiffened flat bottom in order to measure strain, pressure and acceleration at the designated locations by strain gages, pressure sensors and accelerometers and to observe cumulative deformation and deformed shape of the unstiffened flat bottom plate in every wet drop by a surface measurement device.

2. Experimental set-up

A series of wet free drop tests was conducted at the Ocean Engineering Wide Tank, University of Ulsan (UOU), Korea.

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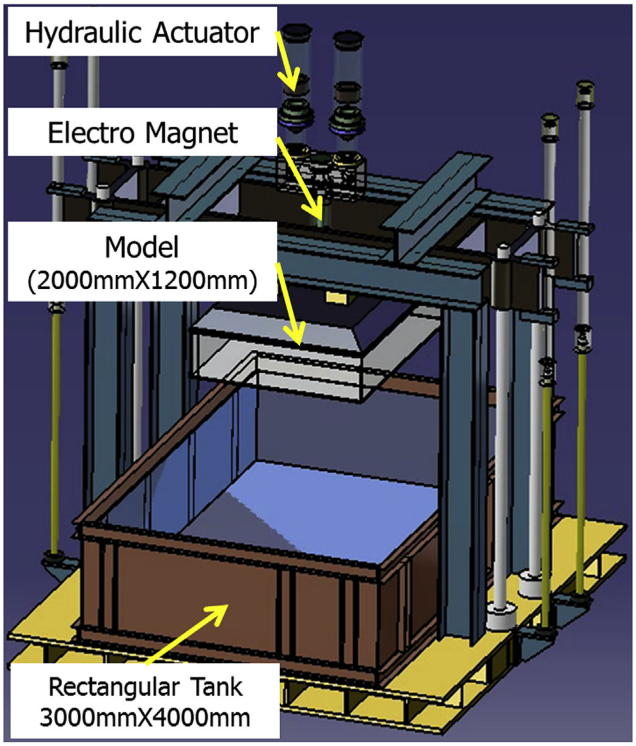

Fig. 1. Wet free drop test facility.

The wet free drop test facility is shown at Fig. 1. In order to obtain the water entry speed resulting from free drops over more than 10 m, an oil pressure actuator system is designed for injection of heavy steel wedges at 2 m above the rectangular tank water surface. A guide rail system with four vertical masts is used to keep the wedge's bottom plate parallel to water plane just before water entry after drop of wedges. Also an electromagnetic system is used to hold a heavy steel wedge before drop and to lift it after drop.

Table 1
Principal dimensions of the body in Fig. 2.

Model	Steel
Dead-rise angle [deg.]	0
Length [mm]	2000
Width [mm]	1200
Height [mm]	300
Mass [kg]	340
Thickness [mm]	3,5,8

A steel body with the unstiffened flat bottom plate of 3, 5 and 8 mm in thickness is shown in Fig. 2. Table 1 shows the principal dimensions.

In Fig. 3 each sensor's location is shown. P1 ~ P8, S1 ~ S8 are the position of pressure sensors and strain gages, respectively.

Fig. 4 shows an extended guide rail. The extended guide rails help the wedge's flat bottom plate to remain parallel to the water surface plane when sliding along the four masts during a drop.

Fig. 5 shows the pressure sensor used in the test and its specifications are in Table 2.

As illustrated in Fig. 6, pressure sensors were embedded on the model surface.

The electrical resistance method was applied to measure strains as in Fig. 7. Table 3 shows the strain gage's specifications. Fig. 8 shows the strain gages glued to the bottom surface.

Fig. 9 and Table 4 show a deflection measurement device separately installed near the test facility.

NI PXI system for data measurement is shown in Fig. 10 and Table 5. Time synchronization equipment is included.

In Fig. 11 the steel wedge conveying system designed for wet drop tests is shown and the process includes the measurement of bottom surface deflections as the final step in each drop.

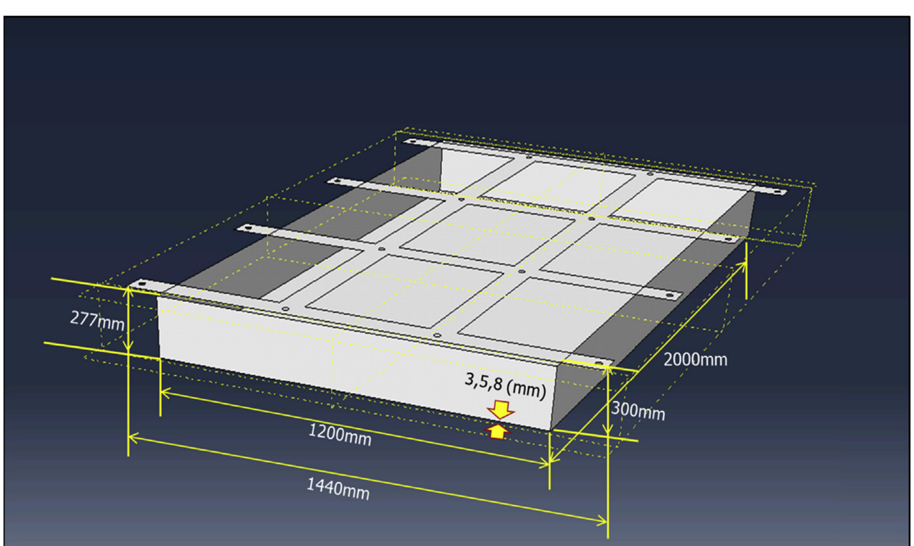

Fig. 2. A steel body with 0° dead rise angle (Unstiffened flat bottom plate).

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