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Investigation of Characteristics of Impact Pressure Pattern in Sloshing Experiment

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ABSTRACT

This paper presents the experimental investigation of characteristics of impact pressure patterns. The irregular motion of motion platform was generated from narrow and moderate band width white noise. Two different filling ratios of 20%H and 70%H were tested. The pressure time histories along with flow field were analyzed depending on the location of the pressure sensors. The analysis revealed major types of impact which are either Wagner type or Bagnold type impact. The combination of these two impacts and other complex pressure pattern were also obtained. The impact pressure patterns and the corresponding flow fields are presented.

KEY WORDS: Impact pressure pattern; ICP type sensor; Sloshing, Wagner type impact; Bagnold type impact

INTRODUCTION

The complex nature of the sloshing phenomenon in LNG (Liquefied Natural Gas) tank needs confirmation of the flow field by pressure measurement. It means that the practical estimation of the sloshing impact load is based on the pressure measurement. Therefore the analysis of pressure time history can be a very important issue in sloshing analysis. The test was done with irregular motion of the motion platform. It was intended to generate various impact patterns.

Therefore it was decided to go with irregular motion. Three types of motions were generated. The irregular motions were generated from narrow band and two other moderate band white noises. The pressures were measured at 54 different locations. The flow field was recorded with video camera to incorporate with pressure time history. The two basic flow patterns in fluid impact are the Wagner type impact (Wagner, 1932) and Bagnold type impact (Bagnold, 1939). These two patterns were witnessed. The combination of these two flow patterns was also obtained. The recorded flow pattern revealed that the Bagnold type impact was caused by air pocket. The Wagner type impact was generated when the impact was due to pure hydrodynamic impact. The pressure caused by the jet along the wall showed typical impact pressure pattern.

EXPERIMENTAL SETUP AND TEST

The sloshing test facility in Pusan National University has the ability to perform 6-degree of freedom motion. The facility consists of a machinery, motion control unit, and related software. The machinery unit consists of an actuator body, actuator/bracket joints, upper and lower frame, and AC servo motor and driver. The actuator is an electric actuator. The motion control unit employs DSP algorithm to control the servo motor. The motion control unit is equipped with safety recovery function so that it can detect any unusual operation of the machine to stop the system in case of malfunctioning. The maximum capacity of 4 tons can be tested with this facility. The overall view of the facility and model setup are shown in Fig. 1. The total motor power to operate this facility reaches up to 90 kW. The model is shown in Table 1. The principal dimension of the model is also shown in Table 1. The model is 1/25 scale model of 138K in the longitudinal direction. The model was made of plexi-glass. The thickness of the model wall is 40mm. The total number of 54 pressure sensors was installed for the longitudinal model. The location of sensors is shown in Table 2. The pressure sensors are Kistler made ICP type sensors. The diameter of the sensors is 5.5 mm. The sampling frequency in this experiment was 20 kHz. The National Instruments PXI-4472B, an extension of the NI 4472 family, was used for data acquisition purposes. NI PXI-4472B provides 8-channel dynamic signal acquisition for the high-accuracy frequency-domain measurements. The eight input channels of the NI PXI-4472B simultaneously digitize input signals over a bandwidth from DC to 45 kHz. This NI PXI-4472B was used with the LabVIEW Sound and Vibration. The irregular input was generated to achieve diverse impact types. Each test was lasted for 10 minutes.

Three white noise spectra with different band width were used to generate irregular waves. The spectra are centered at natural frequency which can be calculated from the following formula

$$f_n = \frac{1}{2\pi}\sqrt{\frac{\pi}{L} g \tanh(\frac{H\pi}{L})} \qquad (1)$$