An Attempt to Demystify Flat Impact

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INTRODUCTION

Flat impact phenomenon seems to be one of the simple impact patterns. However, it has distinct features which are quite different from those of impacts with certain deadrise angles. This study was carried out to perform both the experimental and numerical investigation to figure out this complicated phenomenon. Since not much data has been published about flat impact the experimental work alone is of very useful value. The pressures were measured and the flow phenomena have been recorded by high speed camera. The period of oscillation of the bubbles are measured from video recording to see how this affected the oscillation in the pressure signals. The numerical investigation was also carried out. The air region was solved by finite difference method. Then the free surface was computed by boundary element method. The nonlinear free surface deformation was calculated by semi-Lagrangian method. The comparison between experimental and numerical results was made on free surface deformation, pressure time histories, and period of air bubble oscillation. The comparison between these two results was in good agreement.

EXPERIMENT STUDY

The experiment was done in a wave flume whose dimension is 1800mmx347mmx400mm. An air pressure cylinder was used to achieve flat impact. This forced impact has advantage over the traditional free fall due to its excellent repeatability. Fig.1 shows the wave flume. Two box-type models were used in this study. One model with size of 306x306x70mm was tested as shown in Fig. 2. Another model with size of 280x280x70mm was tested as shown in Fig. 3(a). The experiment was done with pressure gauges only with size of 280x280x70mm. The 4 pressure sensors were installed to measure the impact pressure as shown in Fig. 3(b). The specification of the pressure sensor is presented in Table 1. The high speed camera was used to capture flow pattern of the impact. The maximum speed of the camera reaches up to 78,000 frames per second. The camera speed used in this study varied from 4000 frames per second to 8000 frames per second. The specification of the camera is presented in Table 2. The impact speed of the specimen with water surface was 2.09m/s. The speed of the model was analyzed with the software provided by the camera maker. The water depth was 300mm. The initial height of the model from the free surface was 280mm. (2009).

NUMERICAL STUDY

Finite difference approximation method calculated compressible air region. (Koeheler, 1977). Staggered grid system was adopted for air particle velocity and density of air. The air region was modeled as one-dimensional. Pressure values are calculated from adiabatic relation between pressure and air density. Water region was solved by boundary element method. Constant panel method was used. The nonlinear free surface deformation was calculated by semi-Lagrangian method. The trapped air layer thickness was calculated following the analysis of Kármán's momentum theory (1929) and Mitsuyasu's leakage theory (1966). After the contact of the plate with the water, the trapped air region was idealized with constant thickness. The pressure time history of the trapped air was obtained from the thickness of the air pocket.

ANALYSIS

We compared experimental results and those of numerical calculation.

- Comparison of deformation of free surface
  Fig. 4 shows comparison of free surface deformation between numerical calculation and experimental result. Numerical calculation is in good agreement with experimental result.

- Comparison of pressure time history
  Fig. 5 shows comparison of pressure time history between numerical and experimental result. When it comes to the maximum pressure, experimental result was 0.88 bar and numerical calculation gave 1.02bar. Maximum pressure coefficients were 40.29 and 46.7. These values are similar to experimental results of Chuang (1965) and Nahm et al (2007). We also observe the oscillation period. Fig. 6 shows F.F.T. result. Numerical calculation of the oscillation period was 335Hz and experimental result was 384.5Hz. They are in good agreement.

- Comparison of air bubble oscillation
  We compare air bubble oscillation period. Fig. 7 shows F.F.T. result of numerical calculation and measured period in experiment. In the oscillation period, numerical calculation was 2.55ms and measured result was 2.75ms. Numerical calculation yielded quite close value with measured one.

CONCLUDING REMARKS

This study presents the results of numerical and experimental investigation on the flat impact. Flat impact features very interesting aspects when it is compared with impact with deadrise angles. Comparison between numerical and experimental results yielded reasonable agreement. The approach taken in this study was rather simple models. However, the proposed numerical modeling was good enough to explain the mysterious physical phenomenon of flat impact.

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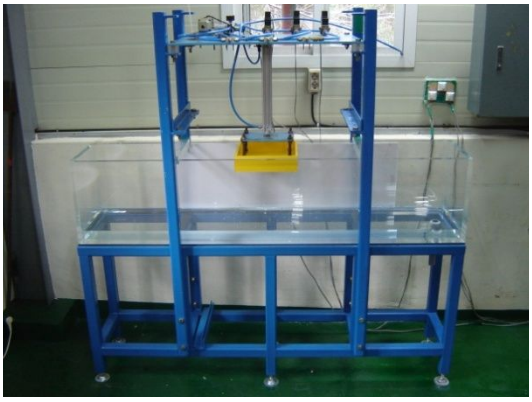

Fig.1 Experimental Set Up

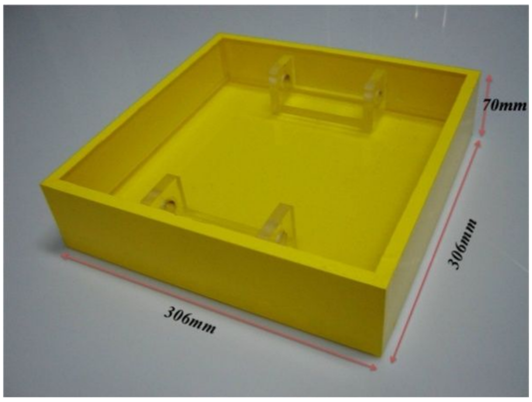

Fig. 2 Specimen Shape & Dimension

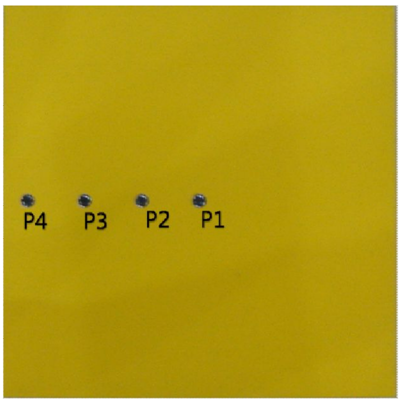

Fig. 3 (a) Bottom View of Specimen

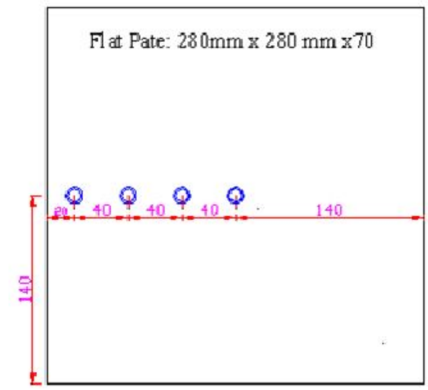

Fig. 3 (b) Dimension & Sensor Location

Table 1 Pressure senor specification

Items	Unit	Kistler 701A
Diameter	**mm**	**9.5**
Range	**bar**	**0~250 bar**
Sensitivity		**80pC/bar**
Linearity	**%FSO**	**≤ ±0.5**

Table 2 high speed of camera specification

Image resolution	**2352 x 1728 at 1000fps**
Internal memory	**4 GB**
Recording rates	**Selectable, up to 78,000 fps**
Control software	**MotionPro X**
Camera to PC interface	**USB 2.0**

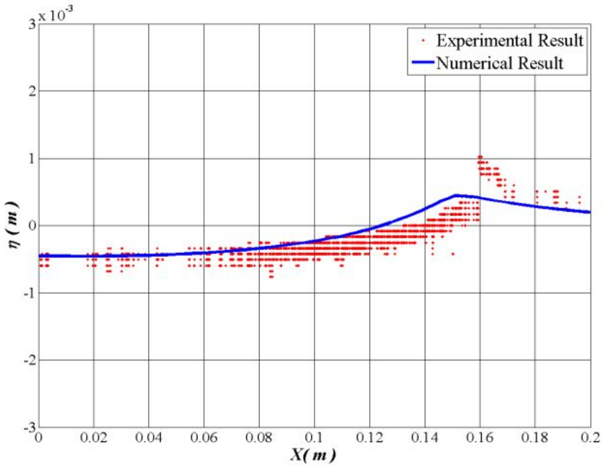

Fig. 4 Numerical and Experimental Free Surface Deformation

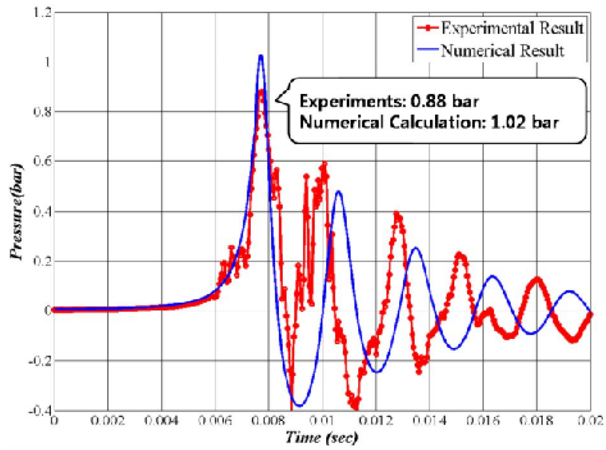

Fig. 5 Numerical and Experimental Pressure Time Histories

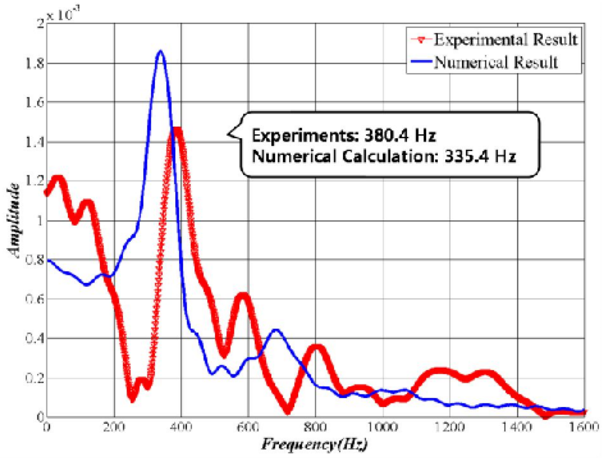

Fig.6 F.F.T of Pressure Oscillations

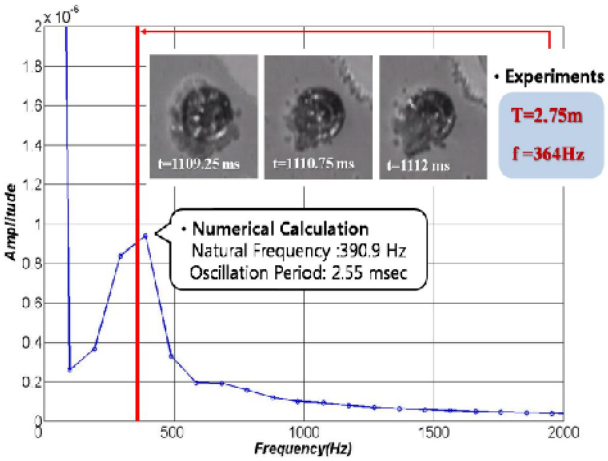

Fig. 7 F.F.T. of Bubble Oscillations