A Close Look at Air Pocket Evolution in Flat Impact

S.H. Oh, S.H. Kwon, J.Y. Chung
[a] **Department of Naval Architecture & Ocean Engineering, Pusan National University, Busan, Korea**
carot541@pusan.ac.kr, shkwon@pusan.ac.kr, chungjy@pusan.ac.kr

INTRODUCTION

One of the simplest forms of water impact must be flat impact. It sounds like simple phenomenon. However, its physics can be very complicated if we take a close look at it. The time history of the pressure due to the flat impact has quite different characteristic when it is compared with those of impact of nonzero dead-rise angles. The pressure signal due to flat impact oscillates and shows negative pressure values. The time history is almost symmetric with respect to the peak pressure in time domain. When it comes to the nonzero dead-rise impact, the time history has high rise and slow release pattern around the peak pressure. These characteristics of the flat impact are due to an air pocket beneath a flat plate. One can see that the air pocket plays an important role in flat impact. However, not much research has been done on this. Faltinsen (1990) pointed out that the presence of air pocket makes the potential theory deviates from the results based on the compressibility of the air. The video image of the air pocket was presented by Chung et al. (2007).

This study presents a close look at evolution of the air pocket in flat impact. The box type model was tested. The side view and bottom view of the flat impact were captured with high speed camera. The evolution of the air pocket was observed clearly. After careful examination of the video images the evolution of the air pocket was classified into three stages in this study. The corresponding pictures were presented to support the analysis. The dimension and duration time of the air pocket for this particular test case was presented.

EXPERIMENT FACILITY AND TEST CASES

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. The box-type model with size of 306x306x70mm was tested as shown in Fig. 2. 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 1. 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 80mm. The initial height of the model from the free surface was 280mm.

RESULTS AND ANALYSIS

Characteristics of the flat impact are the presence of air pocket. The evolution of the air pocket can be classified into three stages. This classification is based on the careful examination of the video images. They are the stages of ripple generation, contact of model bottom with ripples and generation of a large air pocket, and diminish of air pocket. The schematic diagram is presented in Fig. 3. There remains to explain each stage.

Stage 1: Ripple generation before the impact

Some ripples are generated before the impact. These ripples are believed to be generated by the high speed of the air flow. The first appearance of the ripples was shown when the gap between the bottom of the model and free surface is about 6mm for this particular test case. Fig. 4(a) features the side view of bubbles generated around edge of the model. The corresponding bottom view of it is presented in Fig. 4(b). It is believed that the shear stress moves the water particles near free surface. The moving particles meet the stagnated portion of the water. They have to move upward to meet the continuity.

Stage 2: Contact of model bottom with ripples and generation of a large air pocket

The moving bottom of the model contacts with the ripples. This will make trapped air bubbles. They are very small in size. The corresponding side view and bottom view are seen Figs. 5(a),5(b), respectively. A large portion of the bottom of the model have not contacted with water. As a results a large air pocket is generated now. The maximum thickness of the air pocket for this particular case is about 0.9mm as shown in Fig. 5(a).

Stage 3: Diminish of air pocket

As the models travels down the air pocket diminishes. Figs. 6(a),6(b) show the diminished air pocket. Only half of the bottom view is presented.

It took 0.75ms from stage 1 to stage 2. The duration time taken from stage 2 to stage 3 was 2.5ms.

CONCLUDING REMARKS

The flat impact phenomenon has been analyzed with the help of high speed camera. The generation process of the air pocket has been classified into three stages. Each stage was explained with corresponding video images. The generation of the ripples was observed. It seems that these bubbles become small bubbles when they contacted with bottom of the moving model. A large air pocket is generated under the bottom of the model. As the model moves down the air pocket diminishes. The size and time scale of this air pocket was presented in this experimental study. This information can be a very useful to those who want to calculate pressure for flat impact.

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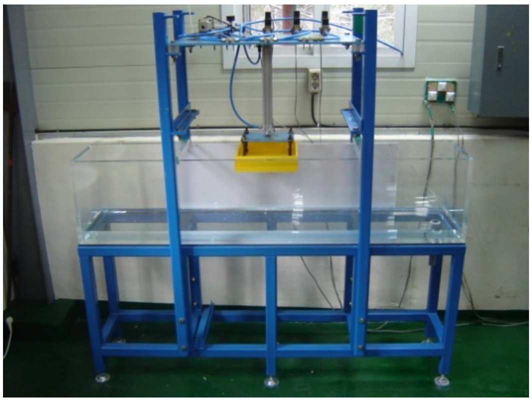

Fig.1 Experimental set up

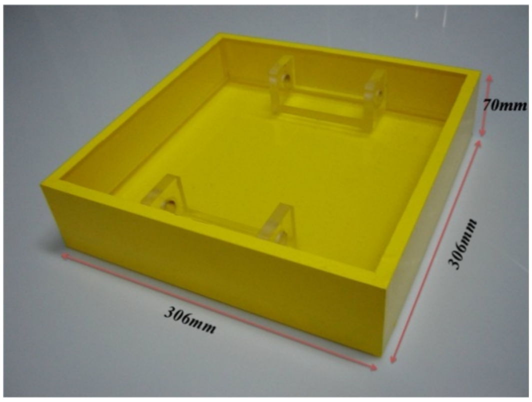

Fig. 2 Specimen shape & dimension

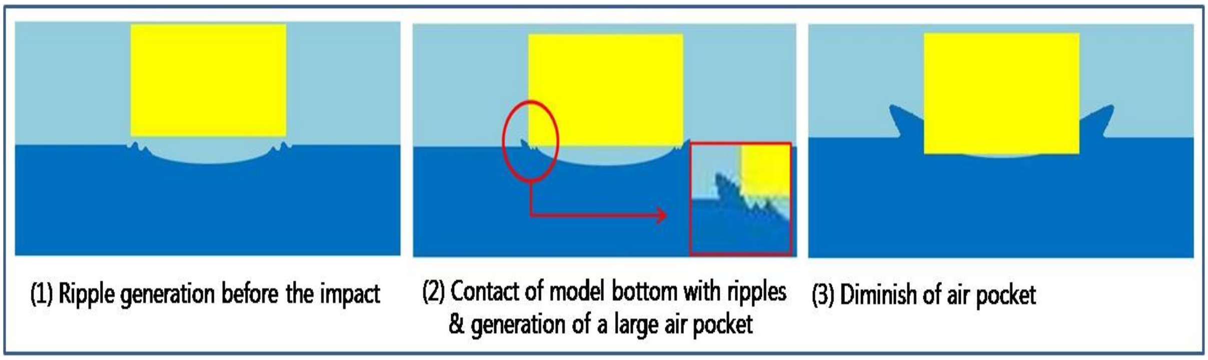

Fig. 3 Three stages of evolution of air pocket

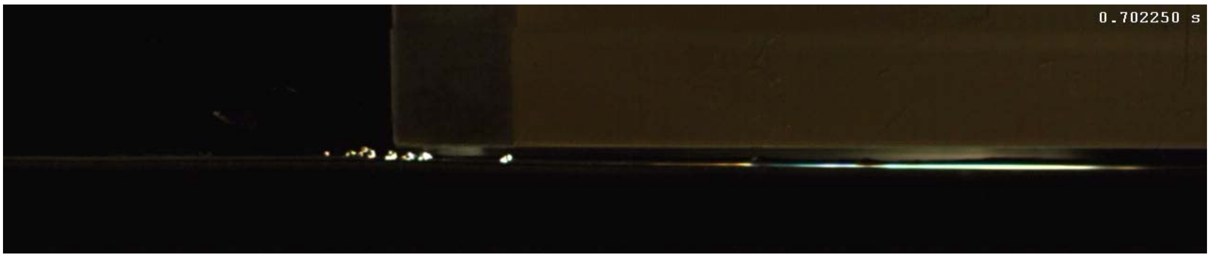

Fig. 4 (a) Ripples generated around edge of model (side view)

Fig. 4 (b) Ripples generated around edge of model (bottom view)

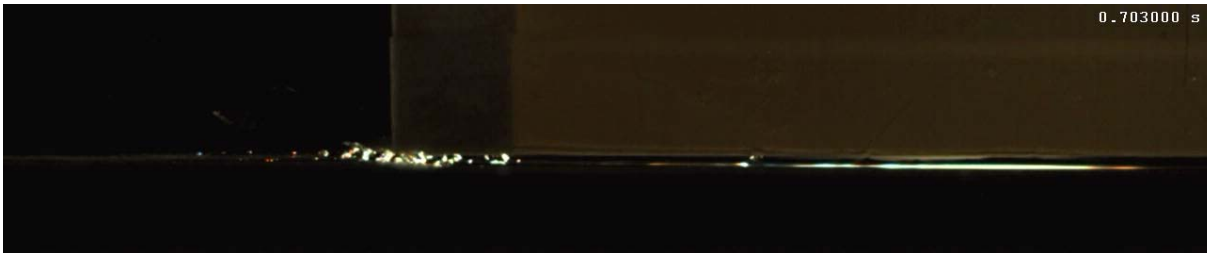

Fig. 5 (a) Contact of model bottom with ripples and Generation of a large air pocket (side view)

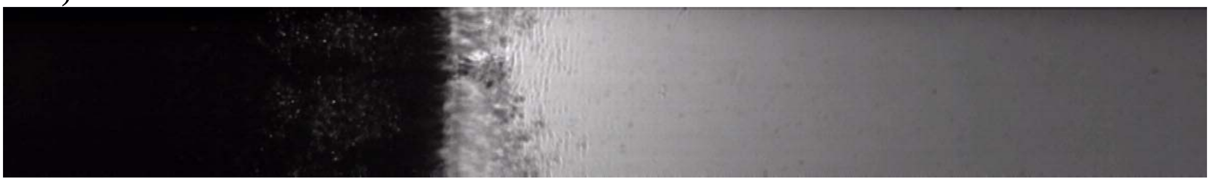

Fig. 5 (b) Contact of model bottom with ripples and Generation of a large air pocket (bottom view)

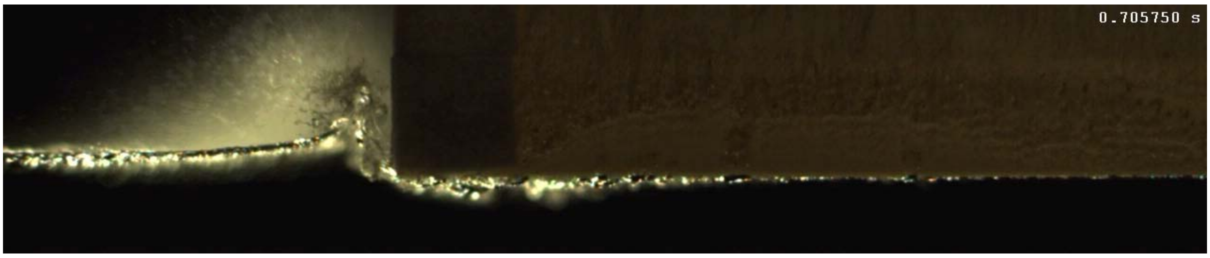

Fig.6 (a) Diminish of air pocket (side view)

Fig.6 (b) Diminish of air pocket (bottom view)

Table 1 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