A Novel Experimental Technique in Slamming

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The pressure coefficients evaluated at various angles of incidence is of importance in slamming analysis. The theory suggested by Wagner (1932) says that the values of pressure coefficient decreases as the angle of incidence increases. When it comes to 0° angle of incidence, the value of pressure coefficient predicted by theory becomes infinity. However, experimental result falls on the value lower than that of higher angle up to around 5°. As a result, the pressure coefficient starts lower value at 0°of incidence and then it increases. Later on it decreases. The present authors tried to explain this discrepancy between theory and experiment in slamming.

Two major factors to explain this discrepancy are jet and air pocket. It is believed that the air pocket plays an important role in low angle of incidence. For higher angle of attack, the jet can be an important factor. The traditional experimental device of slamming relies on free fall. They found difficulty in maintaining its angle of incidence and show the repeatability of incident velocity. The authors of this paper utilized air pressure cylinder which is believed to be very reliable in terms of repeatability. To measure the velocity of the model and incident angle accurately high speed camera was employed. The maximum speed of the camera reaches up to 64,000 frames per second. By analyzing the images we could measure the incident angle and incident velocity of the model.

The incident angle tested ranged from zero to 8° with 1° increment. Beyond 8°, the impact pressure due to slamming becomes very small. Thus one extra point added is 10° which is the largest angle we tested. When it comes to the 0° of incidence, the presence of air pocket is of major concern. As the angle increases, the reduction of air pocket and increase of jet can be expected. Fig.1 shows the snap shot of the slamming. When the specimen came to a complete stop in its lowest position, a large distorted free surface was created as can be seen in the figure. Fig.2 shows the pressure coefficient obtained from this experiment along with pressure coefficient curves suggested by Wagner (1932) and Chuang (1966). The experiment has been conducted three times for the same angle. The velocity is controlled by amount of air trapped in the compressor. As a result, the incidence velocity of the model shows a little bit of variation. This fact also affects the variation in the pressure coefficient. The impact phenomenon has been captured from the bottom of the slamming tank. Fig.3 shows the case when incident angle is zero. In the initial stage the air bubble appeared from the edge of the specimen. Rest of the area is believed to be an air pocket. Later on the area covered by the air bubble increases. Eventually most of the bottom of the specimen was covered by the air bubbles. Fig.4 shows the case when the incident angles are 3° and 5°. One can see the generated jet. To see the jet we had better take a look from the side not from the bottom. Fig.5 shows some of them. As the incident angle increases the jet is detached from the specimen bottom surface.

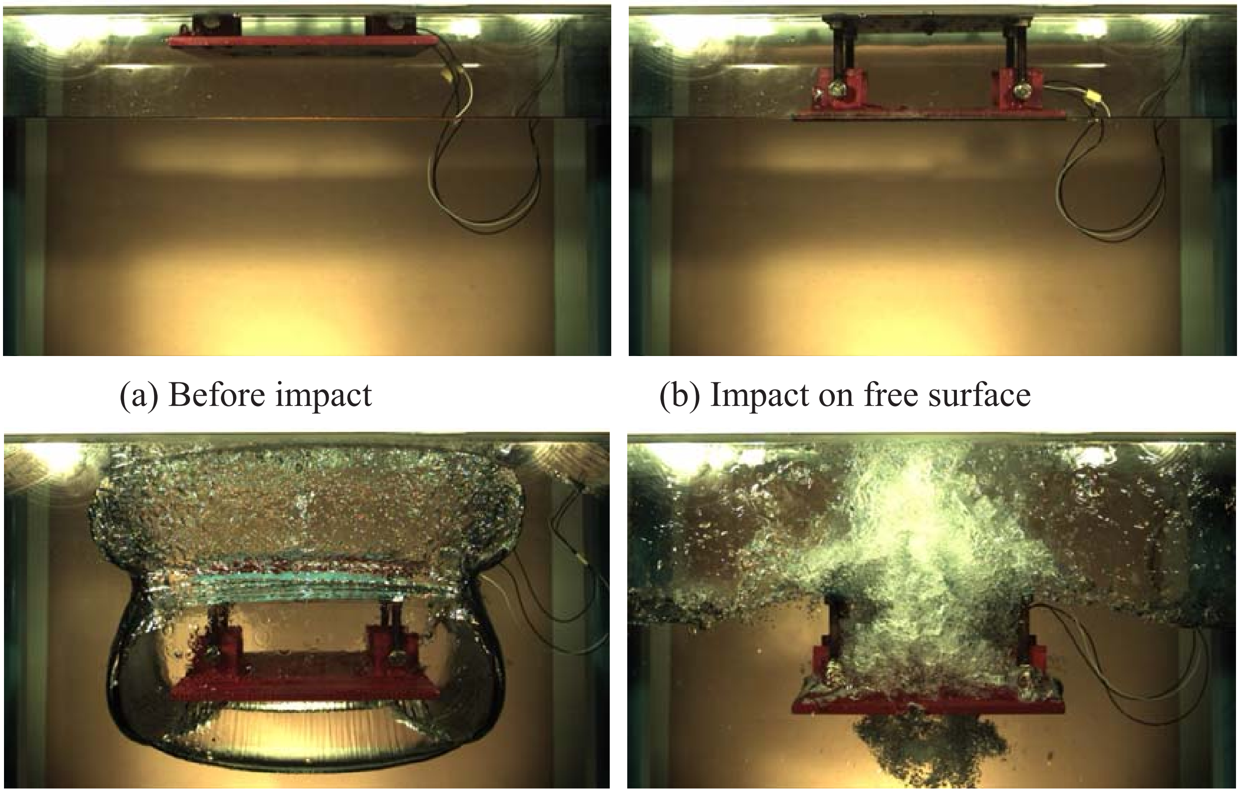
The concluding remarks from this investigation can be made as follows

1) When it comes to the zero angle of incidence, the bubbles are believed to lower the impact pressure.
2) As the incident angle increases, the jet is generated. The balance between the bubble and the jet decides the magnitude of the impact pressure.
3) The magnitude of speed of the jet generated by the impact is very large. As the angle increases, the speed of the jet decreases. Above the incident angle 5°, the jet generated detaches significantly from the specimen.
4) The maximum impact pressure occurs at 2° to 3° incident angles depending on the impact velocity.

References

H. Wagner (1932), “Über Stoss und Gleitvorgänge an der Oberfläche von Flüssigkeiten”, Zeitschrift fur Angewandte Mathematik und Mechanik, 12, 4 pp. 193-235

S. L. Chuang (1966), “Experimental Investigation of Rigid Flat-bottom Body Slamming”, DTMB Report 2041, September



(a) Before impact

(b) Impact on free surface

(c) Complete stop of specimen

(d) Bubble collision

Fig.1 Snapshots of slamming

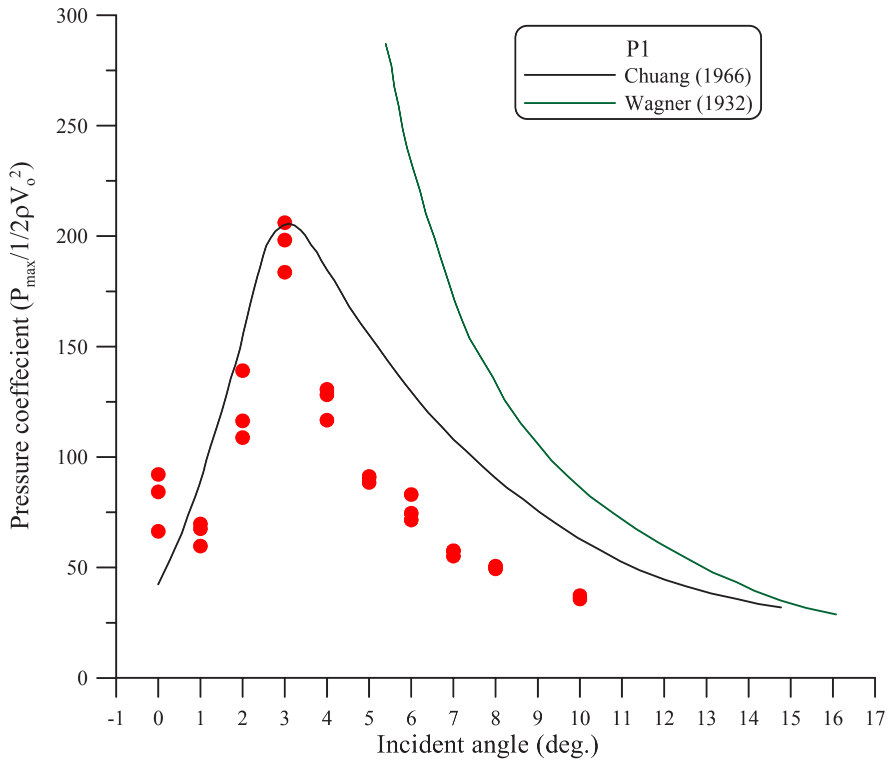


Fig.2 Pressure coefficient

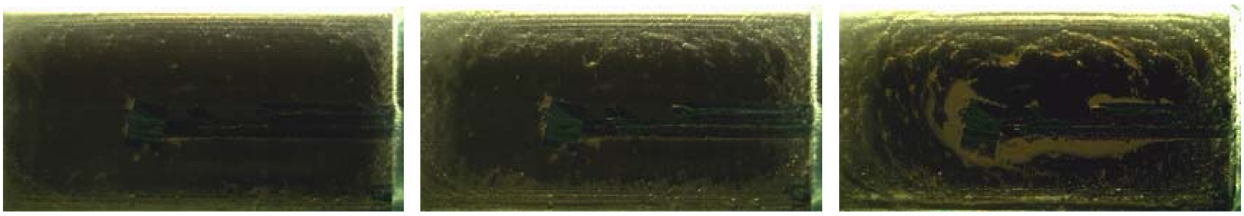


Fig.3 Bubble evolution for 0° incident angle

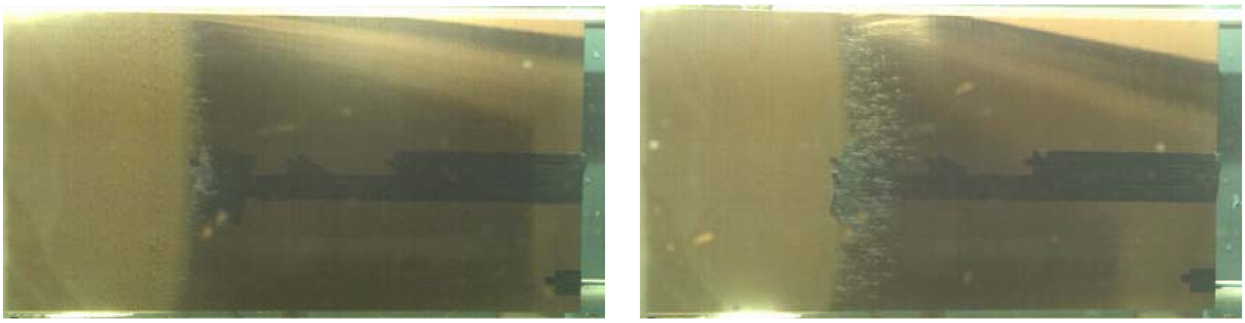
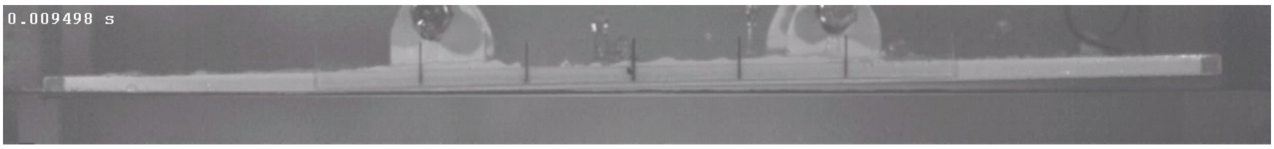
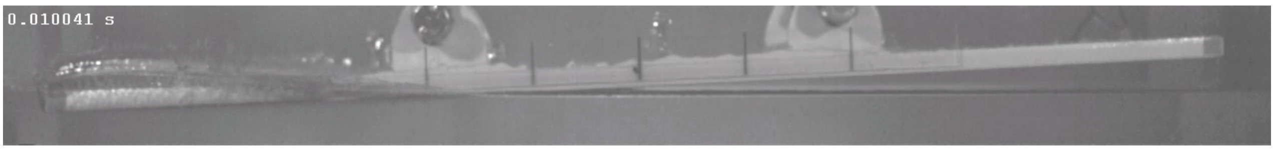


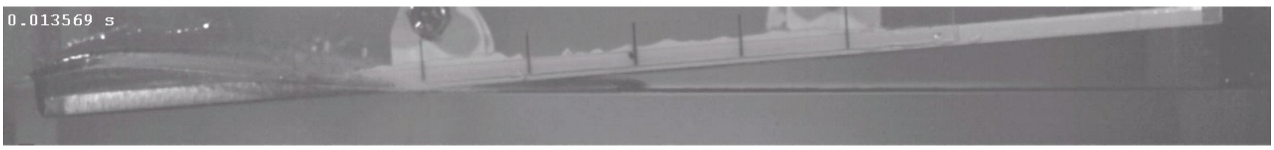
Fig.4 Generated jets for 3° (left) and 5° (right) incident angles



(a)



(b)



(c)

(d)

Fig.5 Jet shape at various incident angle of (a) 1° (b) 3° (c) 5° (d) 7°