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An experimental investigation on dynamic response of composite panels subjected to hydroelastic impact loading at constant velocities

O.H. Hassoon[a,b,*], M. Tarfaoui[a], A. El Malki Alaoui[a]

[a] ENSTA Bretagne, FRE CNRS 3744, IRDL, F-29200 Brest, France
[b] University of Technology, Iraq

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ABSTRACT

Generally, when marine vessels encounter the water surface on entry and subsequently re-enter the water at high speed, this can subject the bottom section of the vessels to high hydrodynamic loads, especially over very short durations. This phenomenon generates high hydrodynamic loads, which can cause a catastrophic failure in the structure. In contrast, the interaction between deformable structures and free water surface can be modified the fluid flow and changed the estimated hydrodynamic loads comparing with rigid body, due to appearance of hydroelastic effects. These effects are considered active challenge areas in structural ship design. This work presents an experimental study of the water impact for composite laminate wedge at different constant entry velocities. The aim of this study is to investigate the dynamic structural response of panels and predicts the hydrodynamic loads to meet the specific requirements of marine vessels. In order to better describe hydroelastic influence, two composite panels with different thicknesses namely 8 mm and 13 mm are subjected under constant impact velocities of 4, 6 and 8 m/s with the deadrise angle of 10°. The obtained experimental results were indicated that more flexible panels had a higher peak force and significant dynamic noise compared with higher stiffness panels. In addition, the maximum deformation occurred in the centre and close to the chine edge of the panel due to changes in local velocity and local deadrise angle. For this reason, special attention requires in both design phase and operation phase.

1. Introduction

Water entry problem is the impact loads between the free water surface and structure which is considered one of critical design issues in ship structures. Therefore, it is recommended to determine the global and local loads. The main early efforts in this area are intensified analytical works in the case of the rigid structure to predicate hydrodynamic forces [1–3].

There are several experimental attempts which have studied the slamming phenomenon to further the understanding of influence of the hydrodynamic loads against ship structures. However, these attempts have concentrated on rigid bodies and most of these have been achieved using drop test impact.

Chuang [4] performed a series of the experiment tests for a wedge-shaped steel body with deadrise angles less than 15° to determine the effect of trapped air. He showed that the trapped air has important influence on the slamming phenomenon with deadrise angles β ($0^\circ < \beta \leq 15^\circ$). Wu et al. [5] analysed the hydrodynamic problem numerically and experimentally for symmetric wedges with different weights, entering velocities and deadrise angles by means of the drop test. They noted that the comparisons between the numerical and experimental results were in good agreement, and that the divergence became increasingly apparent for the deadrise angle less than 45°. They explicated this discrepancy by the air cushion, which leads to a change in the acceleration before and after the wedge enters the water. Tveitnes et al. [6] studied the water entry problem for wedge-shaped section with constant velocity to further understanding of planning and slamming of marine vessels. El Malki et al. [7,8] performed experimental studies for both axisymmetric and pyramidal rigid bodies under constant impact velocity up to 20 m/s using a high-speed shock machine.

The main difference in the hydrodynamic loads between the rigid and deformable structures is the presence of the hydroelastic influence along the fluid-structure interface. This explains why the hull flexibility has significant effects on the design of these structures, which can change the behaviour of the fluid-structure interaction. Moreover, a deadrise angle between the water and the structure is considered to be an important factor to presence this phenomenon, especially small

* Corresponding author at: ENSTA Bretagne, FRE CNRS 3744, IRDL, F-29200 Brest, France.
E-mail address: omar_hashim.hassoon@ensta-bretagne.fr (O.H. Hassoon).

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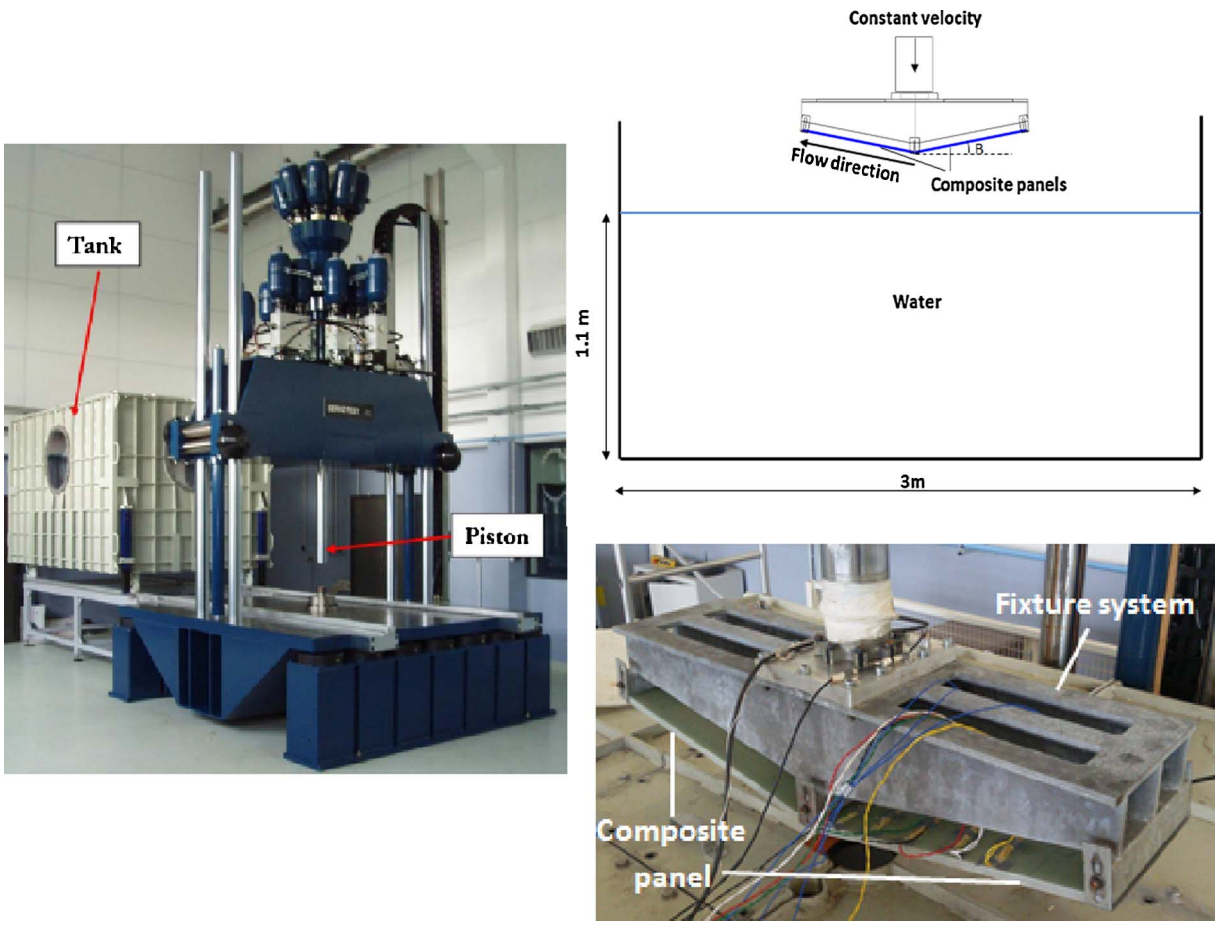
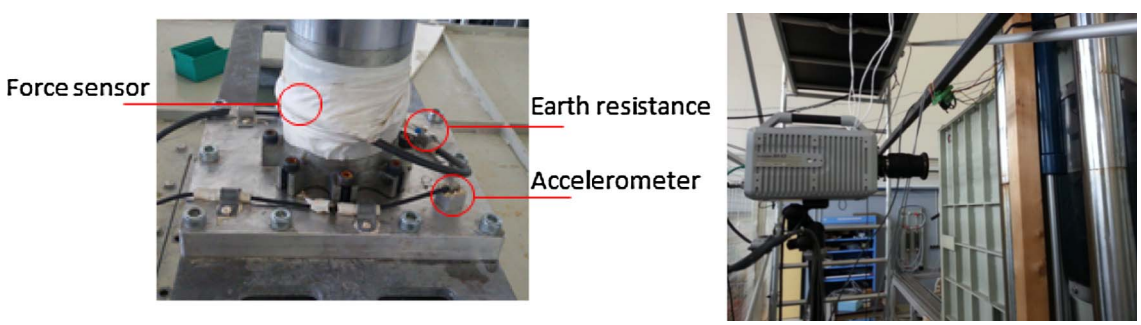


Fig. 1. Test apparatus: Experiment setup and schematic representation.



(a) accelerometer and gauges *(b)* High speed camera

Fig. 2. Measuring devices.

deadrise angles [9,10]. The hydroelastic effects exert of both dynamic and kinematic influences. The dynamic effects occur due to the interaction between the water and the structure, while the kinematic effects are produced due to the inertia effect and the change in the local deadrise angle along fluid-structure interface [11].

The fast development of composite materials in the last decade has encouraged the use of these materials in naval structures, due to their lightweight, high strength and stiffness to density ratios. For this reason, many researchers have studied their behaviour to ascertain the performance and reliability over the life time. Consequently, this assists ship designers to estimate and specify hydroelastic effects and damage mechanism before suggesting a final design load.

Huera-Huarte et al. [12] experimentally investigated the water entry problem on flat sandwich panels at impact velocities over than 5 m/s. They reported that the loads predicted by the asymptotic theory were in good estimation with the experiment data for deadrise angles greater than 5°. For rigid body with small angles, the cushioning effect produced by trapped air appearance in the initial impact duration. Panciroli et al. [13,14] investigated the water impact problem for the deformable wedge, using experimental and numerical approaches. Their results showed that under different boundary conditions, the hydroelastic influence depended highly on the ratio (R) between the first natural frequency of the structure and the wetting time. Therefore, they used a variant of the panel's stiffness and cantilever boundary condition to obtain a large deformation which made the hydroelastic effects easy to measure and investigate. From these results, they supposed that the hydroelastic influence was important for values of R less than 1, and that the same hydrodynamic pressure was produced when comparing with rigid bodies.

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