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A comparison between the experimental and theoretical impact pressures acting on a horizontal quasi-rigid cylinder during vertical water entry

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A B S T R A C T

This paper presents a detailed study on the local pressures acting on the surface of a quasi-rigid cylinder during vertical water entry into a flat water surface. This water entry event is an approximation of bottom wave slamming of cylindrical structures, which is a typical problem for many naval constructions. Hence, the results from this research can be used during the design of cylindrical structures in a slamming sensitive environment. The paper shows the impact pressure results of a large set of slamming drop experiments with a cylindrical model, on a rigorously instrumented test set-up using state-of-the-art equipment. The obtained experimental data is compared in detail with the governing theoretical formulations concerning cylinder slamming. For deadrise angles larger than 4.25°, a good agreement is found with an averaged version of the Wagner theory. This indicates that the Wagner theory is a good estimate for impact pressures acting on a horizontal rigid cylinder during vertical water entry, for deadrise angles larger than 4.25°.

1. Introduction

Water slamming is known as one of the most important loads which naval constructions have to deal with. It can occur due to a breaking wave hitting a structure (breaking wave slamming), or by a structure plunging with its bottom into the water (bottom slamming). The water impact can be so violent that it causes severe damage to the structure. This ability of damaging the structure originates from the high energetic density impact which occurs during a very short period, i.e. a few milliseconds after the first contact between the water and the object's surface. It causes very high local pressures which move very fast over the object's surface.

For vessels and other moving bodies, slamming is avoided as much as possible by heading to calmer seas or by imposing a speed reduction in harsh sea conditions (Faltinsen, 1990). However, for offshore constructions with a fixed oceanographic location (e.g. drilling platforms), previous options are not possible.

These fixed constructions are often composed of cylindrical structural members. Floating or fixed platforms and jackets can be taken as an example, since they are built up of many horizontal and vertical cylindrical trusses. The main problem for these constructions is the repeated water entry and exit of the cylindrical construction elements located in the splash zone of the waves. Especially in heavy sea conditions, the velocity at which these cylindrical elements enter the water can be so fast, that large bottom slamming loads occur. This type of situation also often occurs at the cylindrical bulbous bows of large ships in heavy sea conditions and may also introduce possible hazards during pipe-laying at moments of large waves. These examples of cylindrical bottom slamming events are illustrated in Fig. 1.

Cylindrical bottom slamming is thus a common problem in many applications. It is important to have precise information on the level of slamming in a specific situation to judge if it poses a possible hazard to the complete construction. Mostly, the degree of slamming is characterized by the magnitude of the impact pressures which occur at the object's surface during water entry.

Widely accepted theoretical formulations on these local pressures occurring during cylindrical slamming were derived by

Abbreviations: PVC, polyvinylchloride; ICP, integrated circuit piezoelectric; MOSFET, metal-oxide-semiconductor field-effect transistor; DTC, discharge time constant; DIC, digital image correlation

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Fig. 1. Examples of cylindrical bottom slamming.

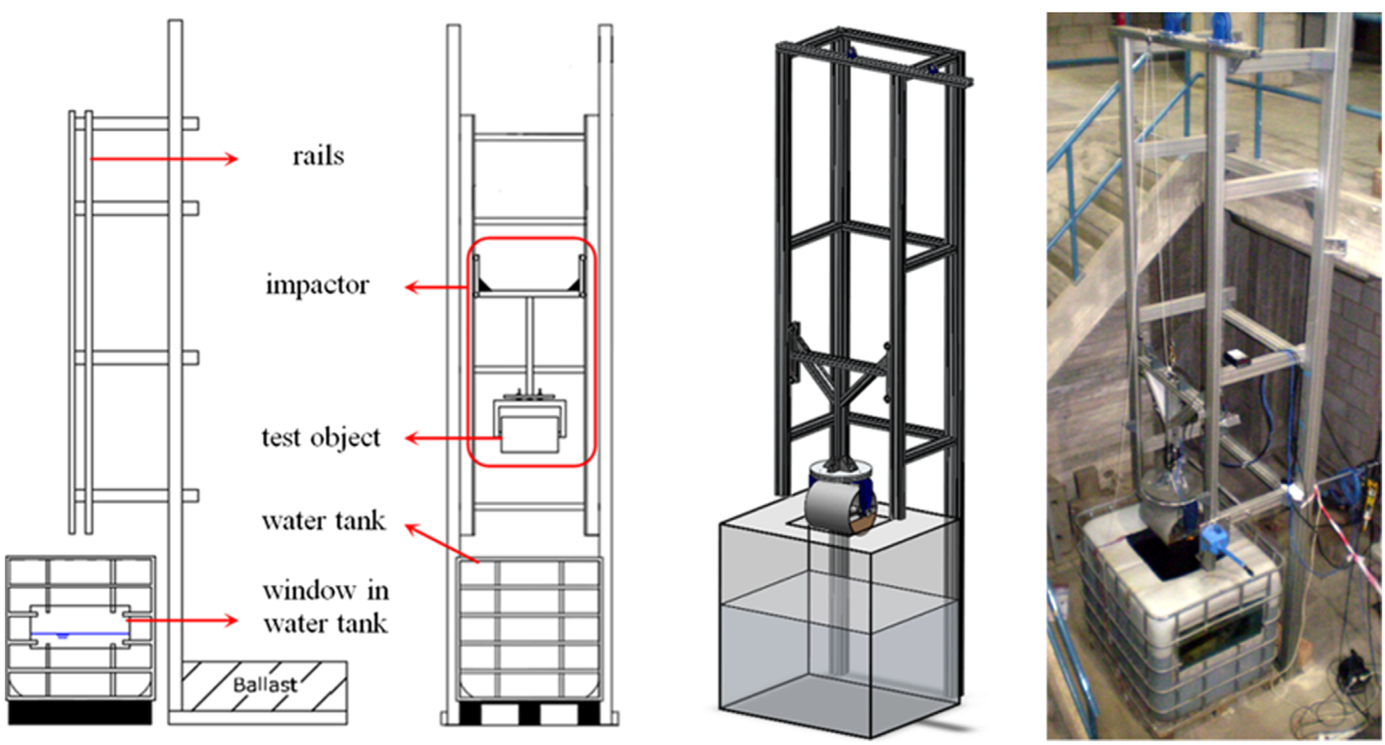

Fig. 2. The experimental test set-up: (a) schematic side view; (b) schematic front view; (c) CAD drawing; and (d) photograph.

von Kármán (1929) and Wagner (Wagner, 1932). However, little experimental information has been gathered in the meantime in order to validate these theoretical models. Greenhow and Lin (1983) performed drop experiments on a cylindrical object, but only focused on the flow around the object during water entry. Campbell and Weynberg (1980), Lin and Shieh (1997) and Colicchio et al. (2009) performed pressure measurements during similar experiments, but it has been shown in Van Nuffel et al. (2012) that these publications used a data sampling rate which is too small to obtain reliable data for estimating the maximum