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Review

An indirect method implementing effect of the wind on moored ship experimental tests

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ABSTRACT

Traditionally, moored ship tests with small-scale models only take into account the disturbance effect of waves. In this paper, the design and testing of a system also implementing the effect of wind in moored ships is analysed. The system is based on rotatory actuators acting on linear springs. This solution has a swift enough response to reproduce the fluctuating component of the wind. Three scenarios have been tested: waves, wind and combination of both. In order to assess the results, different sensors are connected to a computer for data acquisition, allowing the recording and subsequent analysis of the measured variables (forces in ropes, reactions in fenders and ship motions).

The results obtained from the experiments show a great impact when wind effect is considered. A superposition effect is observed when waves and wind act together on the ship, emphasizing therefore the importance of taking the wind into account in berthed vessel tests, achieving safer and more realistic results.

Contents

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1. Introduction

Small-scale model testing is a very useful tool, and in some occasions the only reliable tool, in order to predict the behaviour of real-scale phenomena (Xian-Ying et al., 2014; Hughes, 1993). It is clear this in not a modern technique and it is recorded that Leonardo da Vinci (1452–1519) carried out tests on three ship models having different fore and aft distribution of volumes (Tursini, 1953), but it is still very useful. In this paper, the particular case of berthed ships is addressed.

In the case of berthed ships, the main purpose of small-scale model testing is to estimate the range of tensions in the ropes, reactions in the fenders and amplitudes of the ship motions, leadings to representative measurements of a real-scale behaviour.

A berthed vessel is considered to be an oscillating system whose motions are restricted by mooring lines and fenders, and is therefore subjected to external excitations imposed by currents, tides, waves and wind (Gomez Pina and Iribarren Alonso, 1993).

Traditionally, moored ship tests with small-scale models only take into account the disturbance of waves and, in some cases, also tides. The interest in also reproducing the effects of wind as an additional disturbance has been increasing over the last few years (Fujiwara et al., 2006; Haddara and Guedes Soares, 1999). Nowadays however, there are experimental centres capable of performing moored ship tests including this effect (Table 1). Nevertheless, It must be pointed out that the use of wind fans in the case of offshore structure tests, dates back to at least 1990.

Different ways to reproduce wind effect in moored ship tests have been found in the experimental centres consulted. They are listed in Table 1. Those can be divided in two groups: direct generation and indirect generation methods. The direct generation consists in applying an air current directly onto the model, normally by using a set of fans (Fig. 1). This is the natural way to represent the problem since wind effect in terms of forces and moments are easily solved.

The other method, indirect generation consists in applying the previously calculated resultant forces and moments on the model, such that they would represent the wind effect. These forces and moments can be implemented simply by using dead weights acting on the model through pulleys, with air impellers attached to the model, or with a set of force actuators acting on the model. The use of dead weights is justified when only constant forces and moments are expected to be reproduced. The indirect generation methods using actuators or "servo-winches" (a particular type of actuators that use rotatory servo-motors, pulleys and acting lines), seem to be more appropriate than the direct generation, when reproducing the wind fluctuation components, although those rely on an accurate aerodynamic characterisation of the ship model.

According to the documentation consulted, in offshore structures, fans are rarely used and servo-winches are preferred due to reasons of cost and repeatability. However in berthed vessels the use of fans is much more frequent nowadays. Actually, no papers or articles about the use of other methods on berthed vessels have been found (excluding dead weights).

Table 1, shows some of the experimental centres capable to generate waves and wind. The wind generation method is shown in the fourth and fifth columns, although it has not been found clarified whether these methods are applied in berthed vessel tests.

The aim of the present work is the design, testing and analysis of an indirect generation method that implements the effect of the wind on a moored ship. The system uses rotatory actuators acting on linear springs, controlled by a force control loop.

In order to assess the importance of the wind effect contribution when considering its fluctuation component, different combinations of external conditions were tested: waves only, wind only with different directions, and both waves and wind. The train of waves used in the experiments was identical.

Finally, for each testing case, tensions in the mooring lines, reactions from the fenders, and ship motions were measured. Different sensors connected to a computer through their signal conditioners were used, allowing for the recording and subsequent analysis of the measurements.

2. Model experiment

2.1. Model, law, scale

The non-distorted physical model was constructed according to a linear length scale of 1:150. The inertial and gravity forces were far more important to the model than other properties, such as surface tension and viscosity. Therefore, modelling was performed according to the Froude similarity law, without distortions of scale. This means that the scale factor between the prototype and the model is the same in the 3 space dimensions (Hughes, 1993; Chakrabarti, 1998; Blendermann, 1993).

The 3D model of the port was built using the *wire technique* (Gomez Pina and Iribarren Alonso, 1993), that the bathymetry was reproduced with steel wires fixed to vertical rods welded to lengths corresponding to the depth of each point in question. Subsequently, the bottom was filled with gravel, and finished with a 5 cm thick layer of mortar. Finally, the surface was smoothed to minimize friction (following pictures, Fig. 2).

Port facilities (piers, docks and basins) were reproduced with different materials and construction methods. The breakwaters were built using blocks and stones of calibrated weights and dimensions, and the docks were built with bricks and mortar.

The port used for this study was the one showed in Fig. 3. It corresponds to a Spaniard northern port which was built for agitation essays and ship mooring tests. The ship used in the experiments is shown moored at the top-left corner.

2.2. Wave and wind characteristics

The waves used in the tests were adjusted to the JONSWAP spectra (Hughes, 1993; Chakrabarti, 1998). The characteristics of these waves were: Direction N-050-W. Peak period: $P_P=1.21$ s (model), 14.8 s (real scale). Significant height: Hs = 3 cm (model), 4.57 m (real scale). These data were obtained from *Ports of the*