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Experimental investigations into the current-induced motion of a lifeboat at a single point mooring

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ABSTRACT

This paper presents a series of model experiments on the current-induced motions of a 1:40 scale lifeboat at a single point mooring (SPM). The influence upon vessel and buoy motion of the mooring configuration factors of (a) three mooring line (hawser) lengths, (b) four buoy shapes and (c) two buoy sizes have been investigated. A motion tracking algorithm was successfully employed and validated against data from an inertial measuring unit allowing small scale testing without the influence of instrument cabling. The results show that the dominant translational motion, of the model lifeboat at a SPM, is sway and the rotational motion is yaw, with double pendulum-like fishtailing behaviour prevalent. Increasing the hawser length, when no buoy was present, resulted in an increase in the vessel's sway velocity. No significant effects on vessel motion were observed from changes in the shape of the 1:40 and 1:20 scale buoys. However, the presence and increasing size of the buoy was found to increase the sway velocity of the buoy and reduce the motions of the model lifeboat. These results suggest that changes in buoy size influence the motions of the model lifeboat which may enable mooring efficacy to be improved.

1. Introduction

1.1. Motivation

A Single Point Mooring (SPM), defined by the American Bureau of Shipping as “a system which permits a vessel to weathervane while the vessel is moored to a fixed or floating structure anchored to the seabed by a rigid or an articulated structural system or by catenary spread mooring” (ABS, 2014), allows a vessel to self-align to the prevailing waves and reduce the mooring hawser load compared to that if its heading was constrained (Schellin, 2003; Oil Companies International Marine Forum, 2008). To date, the motions of large scale tankers at SPM's, in deep off-shore waters, has been extensively investigated, due to the expansion of offshore oil and gas extraction (Gaythwaite, 2004; Fan et al., 2017).

At the smaller scale, e.g., boat lengths of less than 20 m, there is limited published data on the efficacy of SPM moorings. There are significant numbers of SPM moored boats around the world, including forty belonging to the Royal National Lifeboat Institution (RNLI) and 389 listed marinas in the U.K (Which-Marina, 2015), which employ a variety of hawser lengths and buoy shapes, including spherical, cylindrical, barrel and modular. Coupled with the numerous media reports of yachts breaking free from their moorings resulting in damage and/or rescue crews being called out for example (BBC, 2008; Percuil River Moorings Ltd., 2010; BBC, 2012; IWCP, 2012; BBC, 2013; SeaSurveys, 2013; Yachting and Boating World, 2016a; Yachting and Boating World, 2016b). In addition the U.K's Marine Accident Investigation Branch have reported that, in the ten year period to 2001, eighty five fishermen lost their lives of which six were due to “whiplash from failed mooring lines, mooring lines slipping from fairleads or being struck by failed mooring ropes” (Lang, 2001). There is a need to understand the motion responses of small vessels at SPM moorings.

1.2. Background

The displacement of a rigid floating body can be described by six degrees of freedom: the translational motions along the axes of surge, sway and heave and the rotational ones around them of roll, pitch and yaw Fig. 1. For an unconstrained vessel these can be subdivided into oscillatory (heave, pitch and roll) that invoke restoring forces due to a change in the vessel's equilibrium displacement and non-oscillatory (surge, sway and yaw), (Van Dorn, 1974). However when a vessel is moored at a SPM the catenary mooring chain provides a restoring force and oscillations can additionally occur in surge, sway and yaw, each mode with its own natural frequency providing the potential for large

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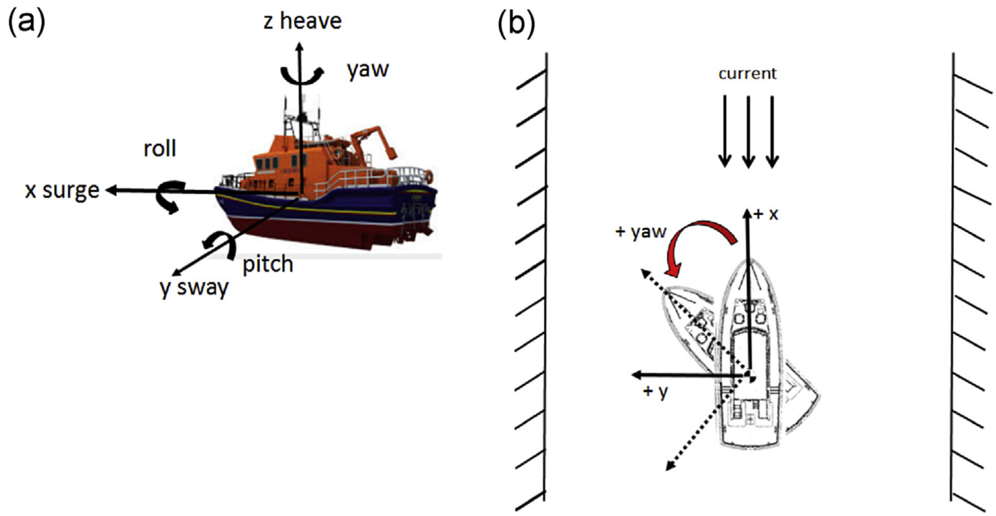

Fig. 1. The right handed frame of reference in the flume (a) three-dimensional and (b) two-dimensional representations.

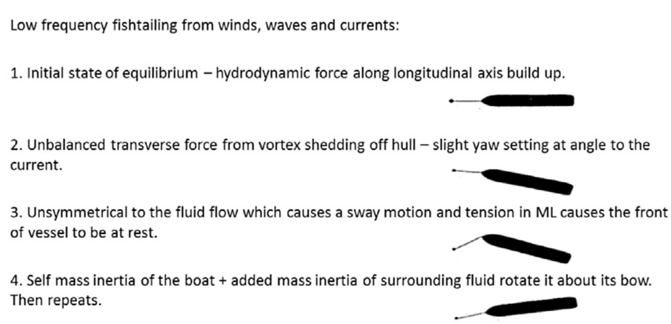

Fig. 2. Fishtailing motion of a vessel at a single point mooring adapted from Aghamohammadi and Thompson (1990).

amplitude motions at their resonant frequencies (Van Dorn, 1974). One of the observed behaviours in wind and current, both in experiments and from mathematical modelling, is termed "fishtailing" (e.g. Aghamohammadi and Thompson, 1990; Luai and Zhi, 2013; Schellin, 2003; Sharma et al., 1988; Wang et al., 2007; Wichers, 1988). This slowly varying drift motion, in the horizontal plane, is described by a combination of the oscillatory motions of surge, sway and yaw around the buoy (Fig. 2).

Experiments performed using model offshore tankers in deep water show this swinging double pendulum-like motion can be reduced by

Table 1
Principle characteristics of RNLI Severn lifeboat and measured values of model with percentage difference of model values compared to full scale at a ratio of 1:40.

Particular	Full scale	Model actual	Percentage difference to 1:40 scale
Length overall (m)	17.30	0.443	2%
Beam (m)	5.92	0.164	10%
Draught (m)	1.78	0.0520	−14%
Displacement (tonnes)	42,300	0.856	−23%
Yaw radius of gyration (m)	4.32 (estimated)	0.1061 (measured)	2%

reducing the hawser length (Pinkster and Remery, 1975) or increasing the hawser tension (Sorheim, 1980). A literature review has found numerous publications detailing experimental data on the motion responses of offshore tankers at SPM but only one relating to small vessels which examined the motion of a fishing boats moored at jetties (Oosugi et al., 2007). The authors are unaware of any literature presenting experimental data on the effect of buoy shape or buoy size upon the motions of small vessels, such as those of the RNLI, stationed at catenary SPM in coastal harbours.

1.3. Paper contribution

This paper presents the results from a series of 1:40 model scale

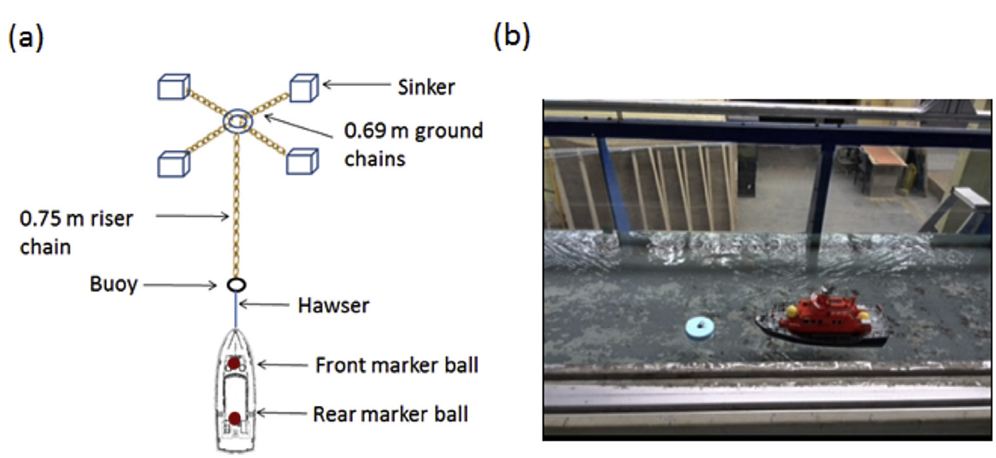

Fig. 3. (a) Aerial schematic of experimental set up. (b) Photograph of model boat in flume (1:20 scale buoy).