SCALE MODEL TESTS OF SHIP IMPACT ON FENDERS

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Abstract. In this study ship's impact on fendering systems upon normal docking procedures is investigated using a scaled model set-up. A set of different loading conditions, speeds and angles of approach were tested. Measuring equipment include a multi-camera motion capture system and force sensors.

Keywords*:* Physical model, ship, docking, fenders.

1. INTRODUCTION

Docking of very large ships is a delicate procedure as the kinetic energy associated with large masses of the ship can result in high impact forces causing damages to the ship, the fenders and even the quay itself. The expected berthing loads are a key element in quay design. Fenders are usually rubbery flexible elements that turn the vessel's kinetic energy into milder reaction forces on the quay by absorbing some of the vessel's energy. The characterization of the docking ship and the forces applied on the fenders are usually quantified with existing design formulae [1][2][3], which assume a single point of impact. However, the pattern and magnitude of impact forces differ for each fender and are highly dependent on the ship's approach trajectory and mass.

Physical model tests on this subject are scarce and can provide relevant information to characterize the maximum force applied to the individual fenders and its distribution among the set of fenders. This kind of information is not only important to understand the cause of some incidents but also to evaluate existing design formulae's adequacy and to validate numerical models with the same interaction. The main goal of this work is to better understand the relation of the mass of the vessel and the speed and angle of approach and their relation to the force distribution on the fenders.

2. PHYSICAL MODEL TESTS SET-UP

The tests were conducted at a 22 m x 23 m (width x length) tank of the Ports and Maritime Structures Division of the Hydraulics and Environment Department of LNEC but only a range of 4m x 4m was used in this study. The experimental set-up is presented in the Figure 1.

The ship's model is a 1:100 scaled version of "*GulfStream*" oil tanker. The overall length of the ship model is 172,50 cm, width is 24,80 cm, max draught is 9,00 cm and deadweight is 13,124 kg.

Ship's velocity and heading are recorded using an *Optitrack*® multi-camera motion capture system (Figure 1), whereas impact forces are registered using 4 force sensors and a Quantum MX data-acquisition system with *CatmanEasy*® DAQ Software(**Error! Reference source not found.**). Fenders force impacts' magnitude and sequence are analysed.

A set of different conditions for a scaled model ship impact were devised, with the ship's mass ranging from ballast condition, partially loaded and fully loaded, and the ship's approach ranging from strictly parallel to the quay to large angles. Additionally, the ship's approach velocity was also tested in ranging magnitudes. For each test condition 20 to 34 repetitions were performed.

(1) (2) (3) (4)

Figure 1. Experimental setup (1). Ship model and pressure sensors (2). High performance motion capture camera (3). Rigid-body target points array placed on the ship's deck (4).

2. RESULTS

A total of 598 docking tests were performed with 4 Loading conditions (ballast, half-loaded, ¾-loaded and fully loaded), 2 docking speeds range (smooth and fast), 4 docking angle types (lateral <10º, small angle <20º, large angle <70º and stern ~90º).

Figure 2 presents the results for one of the test series T010, which represents a partially (3/4) loaded ship with an approach velocity of approximately 50mm/s (0,5m/s in prototype scale) and angle of 90º (parallel to the quay). This test series has 10 impact repetitions. First impact instant is identified on the force sensors readings and correspondent values for horizontal velocity and angle of attack are extracted at the very same instant in time. After a systematic post-processing of all the tests, the maximum impact force is correlated with the docking speed.

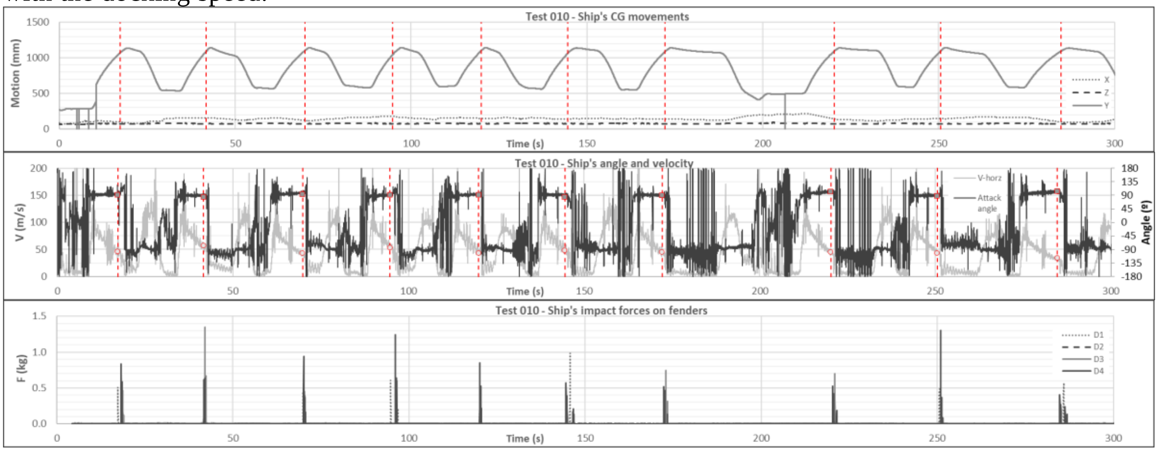

Figure 2. Test series T010.

Figure 3 shows the ship's impact forces on defenses for 3 loading conditions and the comparison with British Standards (BS 6349-4:2014) force $F_k = \frac{E_C}{s}$, where E_C is the Energy of the moving vessel, and design force, $F_d = F_k \times 2$, which accounts for a safety factor of 2.

The measured maximum impact force seldom exceeds the design force obtained using the British Standards norms.

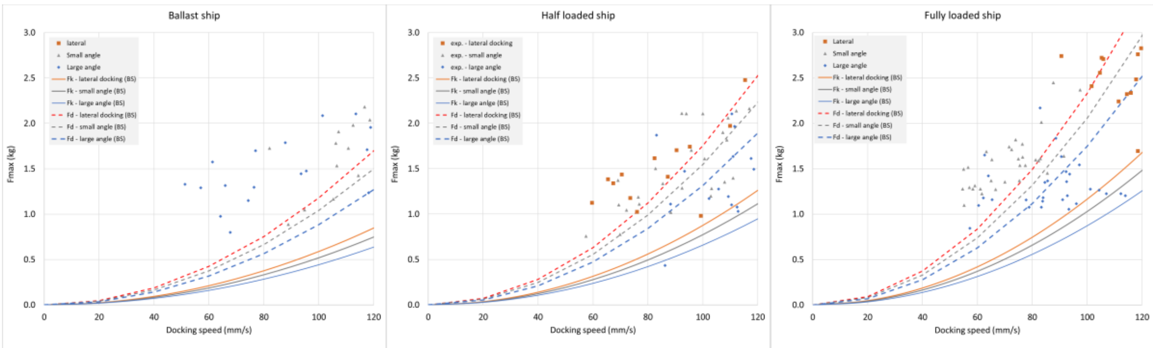

Figure 3. Ship's impact forces on defenses. Comparison of experimental results with British Standards design norms.

Results show that the formulae used to design berthing structures can, in certain circumstances, underestimate the real impact force of berthing ships. One way of adjusting design formulae is to reassess the calculation of the eccentricity coefficient in the energy equation. Alternatively using a higher safety factor for the design force can also be effective.

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