Applied Mechanics on Docking Sequences

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Nowadays many shipyards have their own floating docks for both new buildings and repairs. In view of all the challenging projects these days, many yards have to produce designs which are close to or even beyond the structural limits of their docking facilities. This paper presents a first principle based method to calculate the key numeric values to extend the scope of application of floating docks and platforms.

1 Introduction

At the Pella Sietas shipyard a barge was undocked this year. It was built on the shipyard’s own floating platform. For the docking process the floating platform with the barge on the top had to be dragged out of the harbor basin into deeper water. A major challenge during the floating process was the low residual hydrostatic stability when the deck of the floating platform immersed into water. In addition, due to the absence of side casings, the floating platform has a very low rigidity, therefore it reacts very sensitively to load. Due to this, the entire docking process was calculated at certain points in time and optimized in advance using the calculation method presented. In this way, a suitable sequence of ballast water filling could be specified in order to avoid the risks mentioned. The measured deflections were then compared with the calculated values.

The calculated distribution of the keel block forces was already validated at the end of last year by extensive measurements during a complete docking cycle, as described in [1]. In the following, the underlying theory of the calculation method will be briefly discussed and subsequently the described application will be presented with the measurements and calculation results.

2 Theoretical Background

The calculation method consists of three main routines, that are coupled with each other. In these routines the hydrostatic stable equilibrium, the block force distribution and the bending lines of ship and dock are calculated.

Hydrostatic equilibrium is given when there is an equilibrium of forces and moments on the floating bodies. It is a stable equilibrium when the waterline area, the transverse and longitudinal metacentric height are greater than zero, as described in the lecture notes [2]. During docking, three types of interaction between ship and dock are possible, which are described in [1]. In order to ensure stability at any time during the docking process, the lever arm curve of the overall system for free trim is additionally calculated.

In the longitudinal strength calculation ship and dock are modeled as bending beams that are coupled by nonlinear interaction forces. For this purpose Thimoshenko beams are used in order to consider shear and bending. The external forces resulting from buoyancy and weight distribution are applied as equivalent node forces on the nodes between the beam elements. The keel blocks are modeled as nonlinear spring elements. The nonlinear spring characteristics were taken from the extensive measurements by Kunow [3] and Kulzep and Lehmann [4]. As the keel blocks can not absorb tension, the springs are pure compression springs. The compression of the springs and the deformations of the nodes are calculated using the deformation method and was originally programmed by Greulich [5]. Due to the nonlinear spring elements, the calculation is carried out iteratively. The resulting bending lines change the buoyancy distributions of dock and ship. Therefore, the frames are transformed according to the bending lines and the hydrostatic calculation is done again. Subsequently the strength calculation is performed under consideration of the actual floating position. This outer iteration is terminated when the external forces between the iteration steps do not change.

3 Application: Barge on a Floating Platform

The greatest challenge during the floating process was the low hydrostatic stability of the overall system when the deck of the floating platform immersed into water. Essentially, two measures were taken during the undocking process to avoid the mentioned risk. On the one hand, at the beginning of the undocking process, the platform was bent into a hogging case by

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suitable ballasting. On the other hand, the trim has been increased. By doing so, the waterline area was drastically increased and the parallel immersion of the deck could be avoided. In addition, the barge was positioned as far at the stern of the platform as possible, see Fig. 1. For these reasons the barge started to float at low draft of the floating platform and turned up early. This reduced the load on the deck of the floating platform. While the barge was floating, the draught of the platform increased. Fig. 2 shows the bending lines of the platform $wD(x)$ with the corresponding buoyancy distributions $b(x)$ for selected conditions during docking.

The calculated and measured bending lines of the floating platform are shown in Fig. 3. The values agree qualitatively well. Quantitatively, however, deviations are observed. This is due to the high sensitivity of the floating platform and the simultaneous uncertainties of the measurements during docking. Since the sensors in the ballast water tanks read out the tank fillings on the basis of an equal floating state and are only positioned at one point in the tank, the measured fillings in partially flooded tanks can deviate slightly from the actual tank fillings. This explains why the advanced states 2-3 in Fig. 3 agree quantitatively very well with the measured values, while the early state 1 has higher deviations. The bending lines are determined using an electronic spirit level, that can have measurement inaccuracy, as well.

4 Conclusion and Outlook

The described application shows that the calculation method is a reliable and helpful tool for optimization of docking operations. The docking process is extensively considered and calculated with regard to the hydrostatic stability, the loads transmitted by the keel block system and the longitudinal bending of the bodies. In summary, the comparison of the measured and calculated deflections shows that the values are qualitatively well-matched. Quantitatively, however, there are deviations. These occur due to the high sensitivity of the floating platform and the simultaneous measurement uncertainties during docking. Therefore, a sensitivity study must be carried out for this case.

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References