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IMPACT OF DOCK TANKS PUMPING PLAN ON STRUCTURAL LOADS OF A DOCK AND A SHIP

DOI 10.2478/ntpe-2018-0018

2018
Volume 1
Issue 1
pp. 143-149

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Abstract. Positioning of a ship on a working platform above the waterline in order to repair and modernize the underwater hull parts requires changes from continuous support to point support. And as a result of such, the load of the ship structure is subject to changes as well. In extreme cases, the loads may exceed the allowable loads and cause damage to the hull structure. The paper presents the technical aspects of the ships docking process which may have an impact on safety. It also includes a discussion on procedures that reduce the risk of malfunction and failure.

Keywords: vessels, repairs, docking, floating docks

INTRODUCTION

During the operation, a ship is subject to annual inspections proving that its technical condition meets the standards and requirements of a classification society supervising the ship in order to maintain or renew the certificate ensuring that they continue to meet the parameters of set standards in terms of navigation (Behrendt C. 2016). The preparation process for the survey is usually preceded by repairs. The scope of the inspection is specified in the classification rules and agreements made between the shipowner and the society. A ship must be a subject of the survey of the underwater hull part twice in a five-year validity period of its class certificate (between the second and the third year and after five years of validity period). Additional, unplanned docking is required when the vessel is involved in a marine accident affecting the tightness or strength of the hull structure. Among such accidents, one may find a collision, crash, ship stranding or fire. The aim of unplanned docking is to assess damages and make repairs, if needed, of the underwater part of the hull. Inspections, repairs and modernization of underwater hull parts are related mainly to landing the ship on the working platform above the waterline (Szczepanek M. 2015). Activities related thereto are considered as a docking operation.

Depending on the weight and dimensions of repaired vessels, shipyard equipment and acceptable costs, the operations are carried out using floating docks, hoists or slips or, less frequently due to high cost, by landing a vessel in a basin dry dock and draining the water. In each of the mentioned cases the method of supporting the bottom part of the hull changes from continuous support to point support, which in extreme cases, may exceed the allowable loads and cause damages to the hull structure. The complexity of activities related to preparing and docking a ship may result in the occurrence of threats and risks for safe docking operation.

RISKS EMERGING DURING SHIP DOCKING AT FLOATING DOCK

Floating docks, besides dry docks, are the largest technical infrastructure objects of a shipyard. During the landing a ship in a floating dock, the equal support provided by the water buoyant force is converted into point support by keel blocks. This process is inverted during ship launching. Forces acting on a floating dock during surfacing a ship has been shown on Fig. 1. If the allowable stresses in the keel block material or shell plating are exceeded, the

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ship tilts uncontrollably and structural hull parts or docking devices are damaged and destroyed.

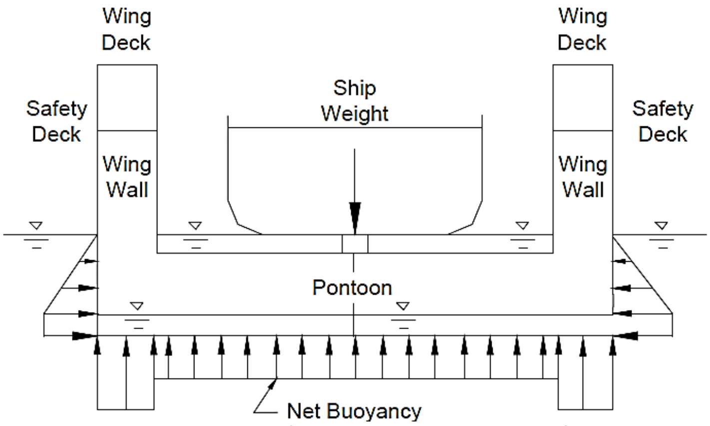

Fig. 1. Forces acting on a floating dock during surfacing a ship.
Source: Author's elaboration based on (Dockmaster training manual, 2005)

The first tasks that should be carried out before docking procedure are commenced is to make basic calculations (Polski Rejestr Statków, 2007) regarding:

- determination of the permissible kill blocks' load and
- stability of the vessel afloat
- stability of the vessel at landing on blocks
- stability of the vessel during undocking.
- The pontoon structure, in other words, the dock deck and bottom, must distribute the concentrated load of the docked ship along the buoyant support of the water pressure. The wing walls structure is designed to increase the dock buoyancy. The safety of the operation performed in the floating dock includes, apart from the ship stability and keel blocks' load, the control of the parameters significant for the integrity of the dock itself (DNV.GL, 2015).
- longitudinal deflection of the pontoon;
- transverse deflection of the pontoon when the ship is supported only along the keel
- transverse deflection of the pontoon when the ship support is distributed equally on the keel and two side rows;
- transverse deflection of the pontoon at the maximum difference of water level inside and outside the wing tanks;
- negative transverse deflection of the pontoon for unloaded dock sections.

Exceeding the permissible stresses as an effect of dock pontoon deflection may have catastrophic consequences for the dock stability. Floating dock, in contrast to other docking machines, must maintain, apart from the structure stability, proper stability during ship docking and undocking. The dock stability is measured by minimum metacentric height and is subject to control at the following docking stages (Polski Rejestr Statków, 2007):

- dry dock at full submergence, no ship;
- partial lift of ship – ship has been lifted approximately ½ its docking draft;
- external waterline at top of the keel blocks (start of minimum stability range).
- external waterline just over pontoon deck (end of minimum stability range).
- dock at normal operating draft.

Preparation of a ship and a dock for docking

Upon having a docking date agreed, technical service of the shipowner provides a docking plan to the shipyard. Before the ship is docked it is necessary to carry out a number of preparatory activities related to the docking procedure, providing power and meeting the requirements for the environment protection. In order to not exceed the stresses of the vessel bottom where block supports are placed, it is required to remove cargo (load), petroleum

waste and to reduce the volume of ballast water to a minimum ensuring the stability of the ship entering the dock. The fuel amount should be also reduced to the least possible level. Upon the completion of the preparatory activities, a summary in a form of a table is developed. It shall include vessel weight, the arrangement of loads, the volume of fluids in tanks, draught. In order to facilitate docking the ship and grounding it on keels, it is aimed to keep the ship on a plate keel, at no trim of the ship. Based on the information mentioned above and the data included in the docking plan, technical options in relation to the dock are selected. These options determine whether it possible to land the ship in the dock and allow for planning the amount and size of the keel blocks, their distribution on the dock platform so that the ship support in provided in locations of higher strength of the ship structure.
The development of the pumping plan, which is a sequence of actions, and the most frequently also a plan for simultaneous ballast tanks draining should ensure that the dock along with the surfaced ship is stable on a keel and that the dock and ship structural stresses are below the permissible ones. Weather data along with the information on the side and frontal surface of docked ship are necessary to specify the required number of tugboats and their pulling force during the docking procedure. The dock, prior to the docking a ship, should be submerged so that the distance between the docked ship bottom and the top edges of the keel blocks is not less than 0.3m (Polski Rejestr Statków, 2007) In certain cases, if impossible to keep the ship stable on a keel, it is allowable to immerse the floating dock with the trim corresponding to the ship trim, however it should not exceed 1.5° (Stasiak, 2005) Due to the safety of the immerge and surfacing operations of the floating dock, it is required to maintain the stability of the dock and the floating dock – vessel unit at every stage of the docking operation(Szozda, 2014). According to the regulations of the Polish Register of Shipping, this value should not be less than 1.4m. Due to the reserve of operation safety, the metacentric height is calculated based on the obtained data so that its value was within the range of 3-5m (Sperski, 2010). The roll value for limit weather conditions is computed if the dock and ship dimensions of the side surface, exposed to the wind, and the dock hydrostatic curves are known. The value of the heeling angle determined for extremely unfavorable weather conditions should not exceed 1.5° (Sperski, 2010). However, usually, it is limited to 0.5°.

Ship docking procedure for floating dock

The process of developing the ship docking procedure for floating docks includes gathering information necessary to plan the docking process, exchange the information and agreement so that every participating party was fully and clearly informed of the adopted procedure, dates and duration of docking. Upon having these activities completed, the ship and the dock are being prepared for the operation. Figure 2 presents the stages of the emerging process for the floating dock – vessel unit. The required actions are as follows:

- distribution of the keel block according to the plan (if support for the sloping surface of the underwater part of the hull is needed, the tightening time should be specified)
- control whether it is possible to immerse the dock in a dock trench;
- control of ship positioning marks in the dock and positioning equipment;
- inspection of ropes, winches, cranes at wing walls, communication systems for the crew.

The docking process is included in the nine basic steps:

- dock immersion with prepared supports up to the specified depth;
- ship towing to the dock by tugboats until the ropes from dock winches are handed onboard the ship; this activity is carried out by a tugboats unit and supervised by a pilot. Until that moment, the ship captain is responsible for maneuvering the ship and the pilot is only an advisor.
- bringing the ship into the dock above the submerged dock pontoon and positioning it correctly. Since the ropes from the dock winches are attached, the dockmaster takes over the accountability for docking the ship and landing it correctly
- starting the pump units according to the pumping plan, commencement of dock emerging process until the vessel bottom touches the keel blocks and further emerging the floating

dock – vessel unit up to 0.03 to 0.05m above the prior ship draft. The ship loses buoyancy and is partially supported on the bottom supports. During that time, it is significant that the towing ropes were properly strung in order to keep the ship in the required position.

- stopping the pumping units, control performed by the ship crew of the correctness of the ship landing at the supports, tightening oblique support (if necessary).
- further dock emersion until the dock pontoon is immersed as planned.
- control of keel blocks and ship supports position
- connecting media necessary during the dock repairs (cooling water, drainage of gray and black wastewater, connecting steam and electricity).
- turning off the ship power devices, switch to power from the dock.

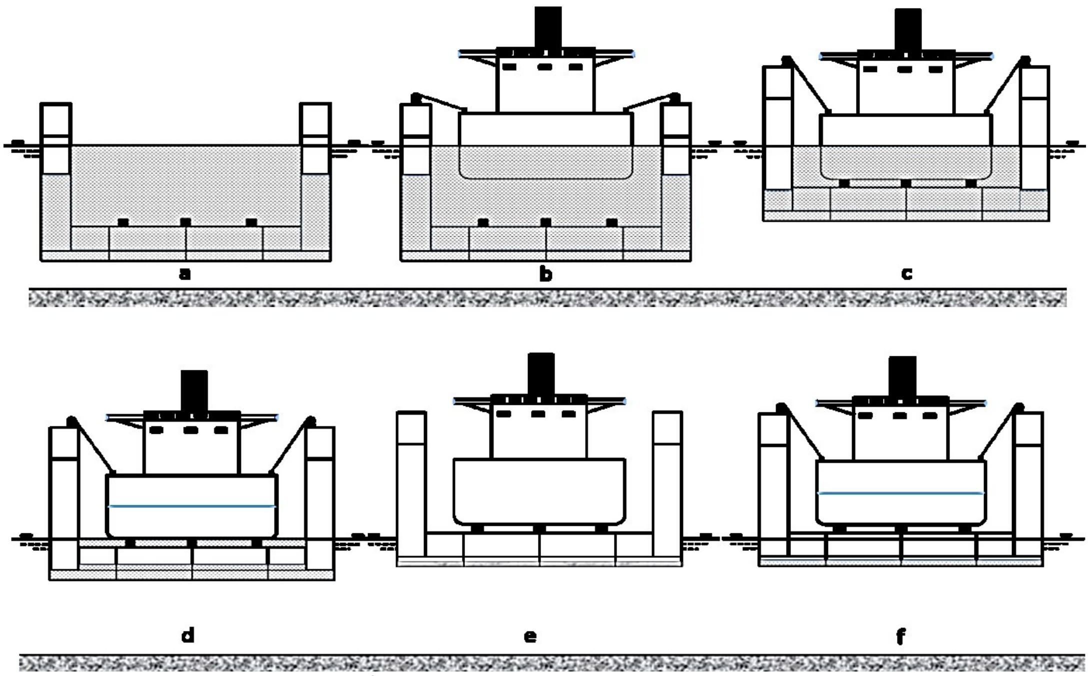

Fig. 2. Emerging phases for a dock-vessel unit (a – dock immersion, b – docking, c – grounding a ship on keel blocks, d – full load of keel blocks, e – pontoon just below water surface, f – dock emerged to the working position)
Source: Author's elaboration

Threats and risks at landing a ship in the dock and during emerging the dock to the working position

The operations of landing a ship on keel blocks and surfacing the dock with the grounded ship at extreme weather conditions or upon the failure to prepare the operation properly may result in:

- damages to the docked ship bottom;
- damages to the dock due to the exceedance of the permissible stresses of the dock structure;
- stability loss of the floating dock – ship unit and displacing docked ship or, in extreme cases, overturning the dock together with the docked ship.

Damages of the ship bottom are mainly caused by using keel blocks of various structure, and thus with different deformation characteristics under load. The most commonly used keel blocks have a steel structure with a wooden coating of the top part interfacing with the ship bottom as shown on Fig.3. For the vessels of smaller dimensions and lower weight, supported on a keel, wooden supports are used as shown on Fig. 4.

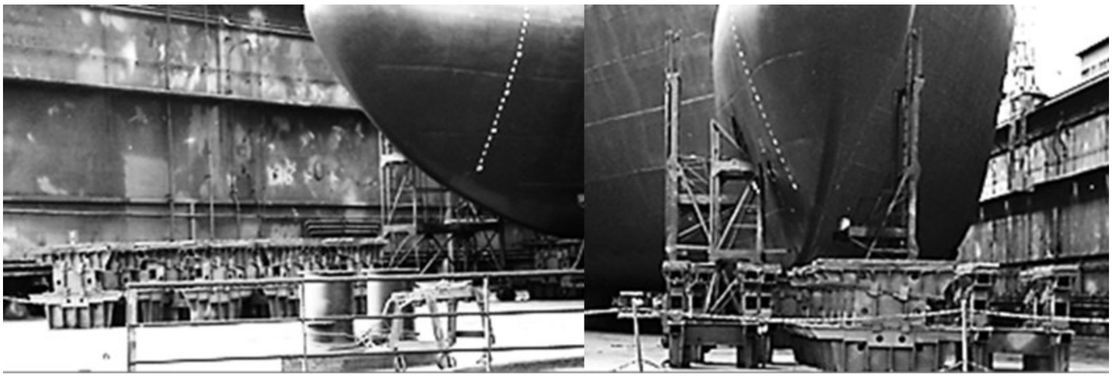

Fig. 3. Steel keel blocks on Dock No. 5 pontoon at SSR.
Source: photo P. Rajewski

Fig. 4. Wooden keel blocks under vessels with reinforced keel.
Source: photo P. Rajewski

Using supports of different structure results in the formation of stresses in supporting points as presented in Fig. 5 which may lead to dents in the shell plating, and even to permanent deformations of the bottom structure (Rozenlit, 1987).

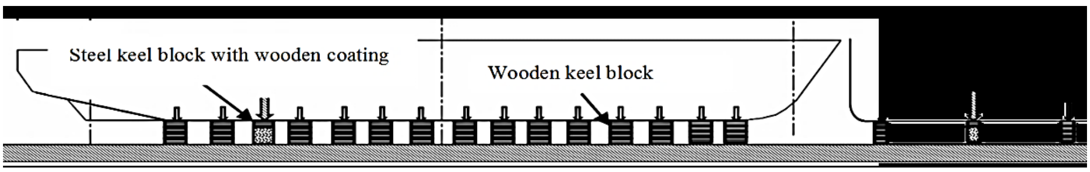

Fig. 5. Various hull pressure on keel blocks of different structure.
Source: Author's elaboration

Due to the failure to land the vessel on the keel, it may lose its stability along with the dock and the hull may be damaged.

If a ship has to be landed on the dock with a tilt on the sideboard due to certain technological reasons (e.g. damage to the ship's hull, full double bottom tanks, as shown on Fig. 6), the changes in pumping plan during surfacing the dock should be considered so as to compensate non-centered support during Phase 1 of emerging the ship (until it is landed on keel blocks) and then return to draining the tanks symmetrically and align the initial tilt.

During the dock – vessel unit surfacing operation, there is a number of critical moments shown in Figure 3 namely Phase d and e. In Phase d water reaches the keel blocks' top, ballast tanks in the wing walls are drained and the water is pumped out from the ballast tanks in the pontoon. In Phase e the dock deck is just under the waterline and the water is still being drained from the pontoon's tanks. The dock – vessel unit stability is the least in the said immersion phases. Even the slight tilt of the pontoon in Phase e may result in water overflowing to one sideboard and the dock stability is disturbed (DNV.GL.M., 2015). Such a situation has occurred in the Remontowa Shiprepair Yard S.A. of Gdańsk during docking a ferry "Princessa Benedikte" which slipped down the keel block. The cause of the incident was a failure of the ballast tanks' valves.

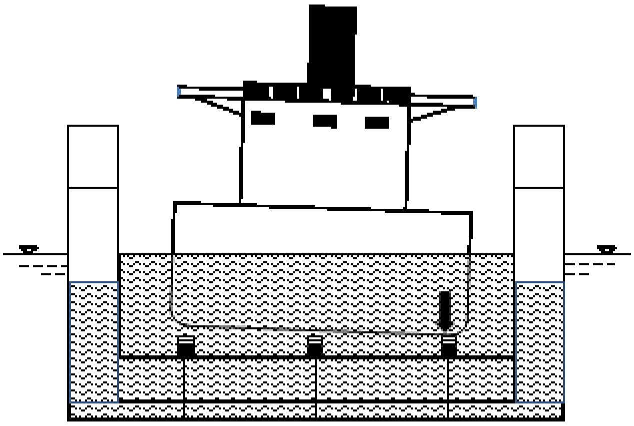

Fig. 6. Difference in hull pressure on keel blocks and change in the point of application of the resultant force when docking a ship with a tilt on the board.
Source: Author's elaboration.

This resulted in the tilt of the vessel and the ferry leaned with its left side against the dock wing wall. Fortunately, no buoyancy of the unit occurred and upon the dock re-immersion the operation was completed properly and successfully. A few months later, in April 2017, a dock with a docked ship overturned in the Nauta Shiprepair Yard of Gdynia (Fig. 7).

Fig. 7. Overflown dock No. 1 and the docked ship at Nauta Shiprepair Yard.
Source: photo Piotr Hukało.

In order to reach the maximum stability during emerging, it would be advisable to pump out the water firstly from the wing wall tanks and then from the ballast tanks of the pontoon. However, this draining procedure applied during the lifting process of a vessel the weight of which is almost equal to the dock lifting capacity causes that the transverse stresses of the dock structure which may cause damage to it. The dock deformations may be transfered onto the keel blocks and damage the shell plating of the supported ship.

CONCLUSIONS

The uniqueness of the positioning and lifting operation of a ship in the floating dock requires the docking plan to be updated before each docking.
Due to the safety of a floating dock structure and its stability, during the surfacing operation of a dock – vessel unit, it is advisable to develop a software or application to determine the landing method on keel blocks and to monitor on a current basis the process of draining the ballast tanks in the floating dock. The software or application should interface with signals collected on-line from dock structure stress controllers, tilt and trim sensors and should

compute the unit stability updated in real time. An alarm system for critical states should also be incorporated(Cepowska, 2014).

The algorithm of the pumping plan for dock tanks should take into account the optimization of the number of the tanks being drained due to the power consumption and the efficiency of the dock pumps.

ACKNOWLEDGEMENTS

This research outcome has been achieved under the research project no. 2/S/IESO/2014 financed from a subsidy of the Polish Ministry of Science and Higher Educations for statutory activities of Maritime University of Szczecin.

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Date of submission of the article to the Editor: 06/2018
Date of acceptance of the article by the Editor: 08/2018