IMPACT OF DOCKING METHOD ON LOADS IN ELEMENTS FLOATING DOCK – VESSEL UNIT

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Abstract
The paper concentrates on how a selected dock surfacing method affects the stresses formation in the structure of the dock and the vessel hull. Repairs and modernization of underwater hull parts are related mainly to placing the vessel on a working platform above the waterline. Docking operations are carried out using floating docks, hoists and slips or, less frequently due to high cost, by entry the 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 multipoint support, which in extreme cases, may exceed the allowable loads and cause damage to the hull structure. The paper presents modern docking equipment and includes a discussion on the docking methods for vessels and technical aspects of the process affecting load variation in accordance with a selected dock surfacing method.

Key words: *vessel docking, floating dock, repairs, docking,*

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. The preparation process for the inspection is usually preceded by conducting repairs. The scope of the inspection is specified in the classification rules and agreements made between the shipowner and the classification society. A ship must be a subject of the inspection 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). Inspections, repairs and modernization of underwater hull parts are related mainly to laying the ship on the working platform above the waterline. 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 dry docks, hoists or slips or, less frequently due to high cost, by entry 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 multi point support, which in extreme cases, may exceed the allowable loads and cause damages to the hull structure *(Rules for classification floating docks, Chapter, 2 Steel hull structures, DNV.GL, Edition October 2015).* Upon having a docking date agreed, technical service of the shipowner provides a docking plan to the shipyard. Docking plan is a document developed by the shipyard constructing the vessel and includes essential information for the shipyard prior to docking the ship. 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 environment protection. In order to reduce the stresses of the vessel bottom where keel block it supports, 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. In order to facilitate docking the ship and grounding she on keels, it is aimed to keep the ship on a plate keel, without trimming of the ship. 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. Figure 1 presents forces acting on the floating dry dock – vessel unit during emerging the ship above the waterline.

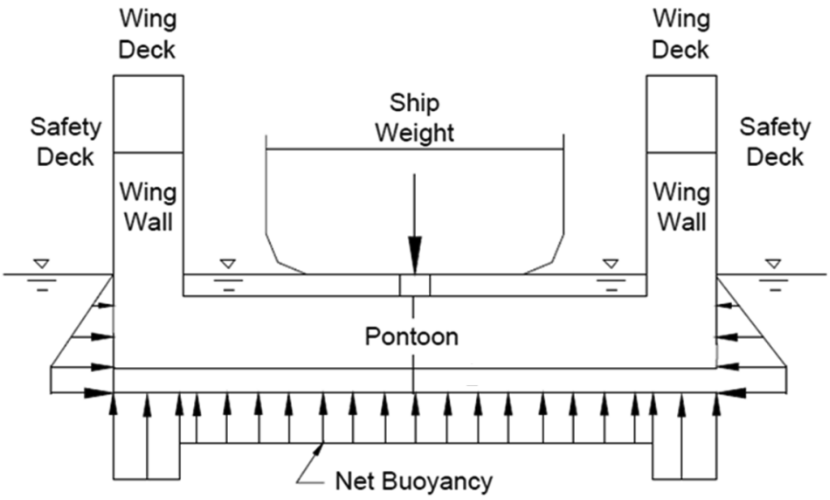

Fig. 1 Forces acting on a floating dry dock during surfacing a ship *Source: Author's elaboration based on* (2)

The paper aim is to present the factors affecting the changes of dock structure loads in reference to Dock No. 5 of repair yard "Gryfia" located in Szczecin, which occurred while docking two vessels namely m/s Narew and m/s Nogat. Different procedures for removing ballasts from the pontoon were applied.

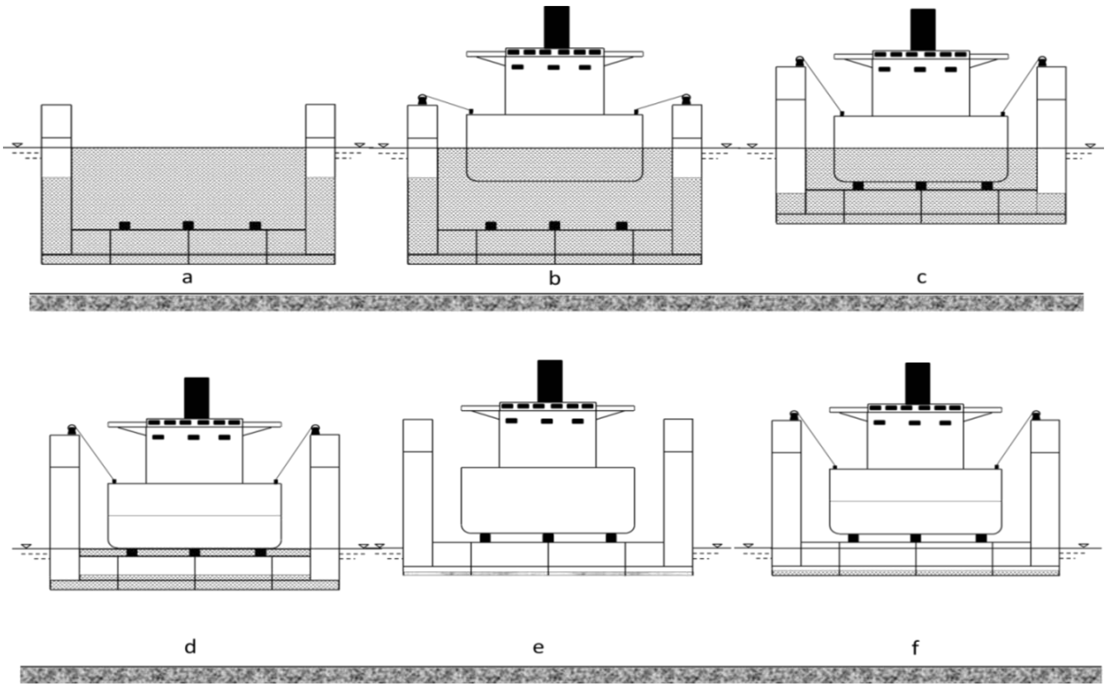

Fig. 2. Emerging phases for a dock-vessel unit (a – dock immersion, b – docking, c – grounding a ship on keel blocks, d – full load of keel blocks, e – pontoon just below water surface, f – dock emerged to the working position) *Source: Author's elaboration*

During the dock – vessel unit surfacing operation, there is a number of critical moments shown in Figure 2 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 above 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 (6). Such a situation has occurred in April 2017 in a Polish shipyard.

MATERIALS AND METHODS

The complexity of activities related to preparing and docking a ship may result in the occurrence of threats and risks for safe docking operation. The main reason for this to happen is local exceedance of allowable stresses of dock structure or docked ship. The design values of bending moment and transverse strength related with loading the dock with the weight of docked ship, dock's weight along with water ballast and buoyant force should not be less than (1):

$$M = k_m g P_D L_D \quad (1)$$

$$Q = k_g g P_D \quad (2)$$

where M is bending moment (kNm), Q is the value of transverse strength in the dock (kN), k_m is a numerical factor of the values provided in Table 1, k_q is a numerical factor of the values provided in Table 1, g – gravitational acceleration (g = 9,81 m/s2), P_D – dock lifting capacity, [t]; the parameter the value of which is equal to the weight of the heaviest ship that may be docked in standard dock operational conditions; L_D – dock's length, [m]; it is a distance between the end walls (transverse bulkheads) of the pontoon (or pontoons), measured in the plane of the symmetry of the dock.

Tab. 1 k_m and k_q values (1)

Dock lifting capacity PD [t]	k_m	1 k_q
≤ 40 000	0,0333	0,13
≥ 70 000	0,0195	0,08

Linear interpolation should be applied to determine k_m and k_q for 40 000 t < P_D < 70 000 t. The formulas (1) and (2) should be applied if dock sagging and bending occurred. The above values M and Q are used to specify the required value of dock cross-section modulus and the cross-sectional area of vertical plates on the wing walls. The k_q value as a function of the dock cross-section is presented in Figure 3 and Figure 4.

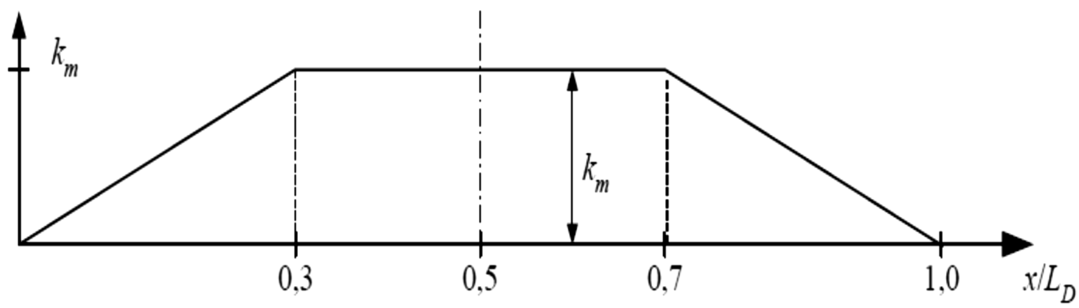

Fig.3. k_m value as a function of the dock cross-section (1)

The stresses in the dock's hull formed by general bending (or general bending including torsion) should not exceed the values provided in Table 2. The acceptable shear stress values, presented in the table, refer to mean stresses the values of which should be calculated by dividing transverse strength by the sum of cross-sectional areas of vertical plates on the wing walls.

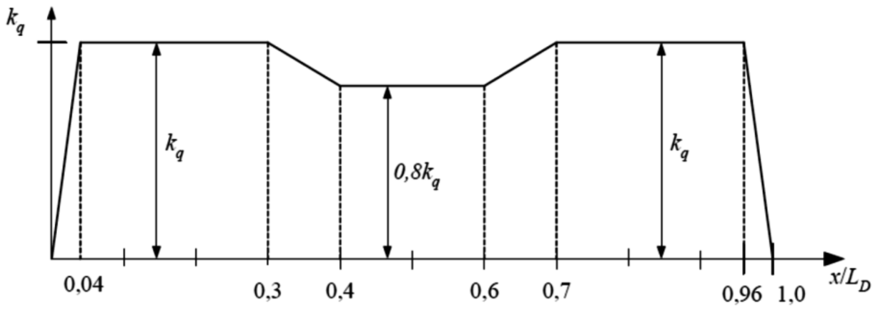

Fig.4. k_q value as a function of the dock cross section (1)

Tab. 2 Allowable stresses for dock's hull (1)

No	Load as per the equation	Normal stress σ_{dop} MPa	Shear stress τ_{dop} MPa
1	1	140k	100k
2	2	200k	120k

The value of strength modulus of dock's cross-section in any point along the dock should not equal less than the one determined as follows (3)(1)

$$W = \frac{M}{\sigma_{dop}} \cdot 10^3 \quad cm^3 \tag{3}$$

where
W is the value of the dock cross-section strength modulus (cm^3),
M is bending moment (kNm),
σ_{dop} is allowable stress (MPa)

The monitoring system of normal stresses formed by general bending and wing walls sagging enables to determine bending moments and stresses in a selected cross-section of the dock. In Dock No. 5 of repair yard "Gryfia", the measurements are read in the control room. Based on the above relation, an impact of dock ballast tanks draining method on bending moment value has been specified.

RESULTS AND DISCUSSION

Based on equations (1), (2) and (3), and by using the measurements of maximum deformations of the wing walls in Dock No. 5, the maximum bending moment values has been determined for two methods of draining water from the ballast tanks of the pontoon and the dock's wing walls. The results are presented graphically in Figure 5. 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 are bigger than when the water is drained simultaneously from the pontoon and the wing walls are presented on Figure 5. In extreme cases, the stresses may cause damage to the dock structure. The dock deformations may be transfered onto the keel blocks and damage the shell plating. On the other hand, 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, or when the transverse stability of the dock – vessel unit is decreased while the water is pumped out simultaneously from the ballast tanks of both the wing walls and the pontoon, may result in the loss of stability of the unit, displacing docked ship (4) or, in extreme cases, overturning the dock together with the docked ship as presented on Figure 6.

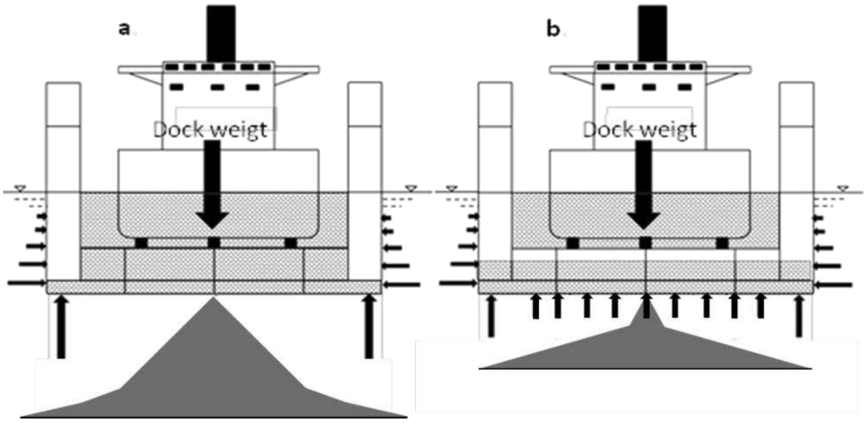

Fig. 5 Bending moments in cross section view for differnt draining methods during emerging a dock – vessel unit – Dock No. 5, a.- bending moment acting on dock's structure when water is drained from the wing wall tanks; b.- bending moment acting on dock's structure when water is being pumped out from the wing wall tanks and pontoon.*Source: Author's elaboration*

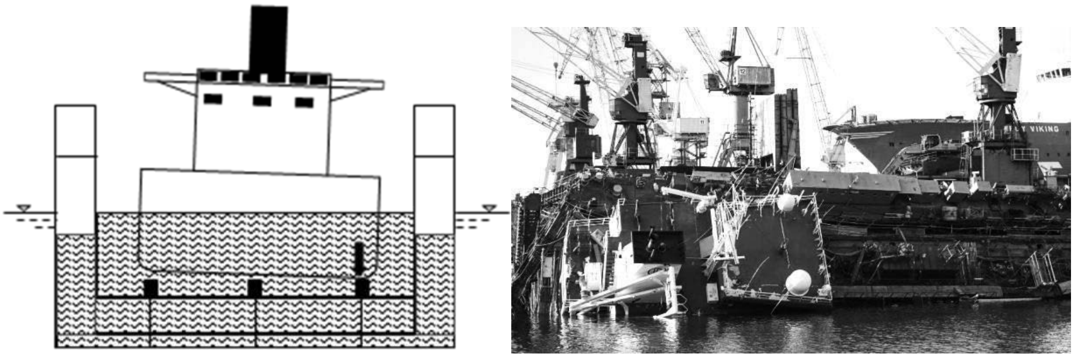

Fig. 6 Difference in hull pressure on keel blocks and change in the point of application of the resultant force when docking a ship with a tilt on the board *Source: Author's elaboration, photo Piotr Hukało*

If a ship has to be landed in the dock with a tilt on the sideboard due to certain technological reasons (eg. damage to the ship's hull, full double bottom tanks), the changes in pumping plan during surfacing the dock should be considered so as to compensate non-centered support during the firste phase of surfacing the ship (until she is layed down on keel blocks) and then return to draining the tanks symmetrically and align the initial tilt.

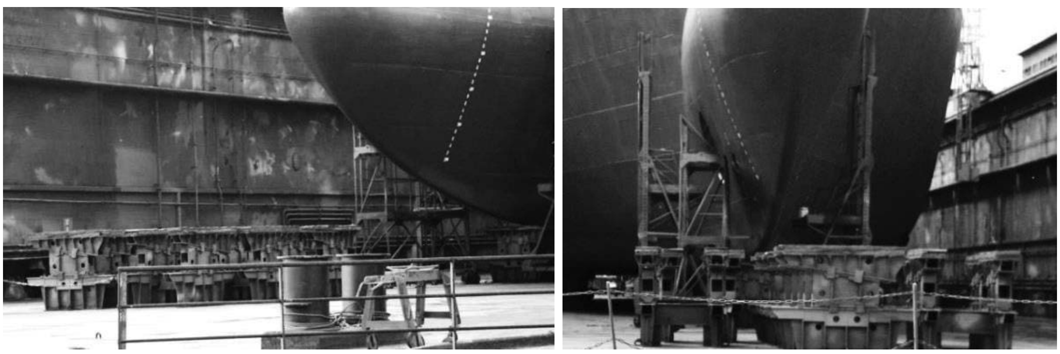

Fig. 7 Steel keel blocks on Dock No. 5 pontoon at SSR *Source: photo Przemysław Rajewski*

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 are presented on Figure 7. For the vessels of smaller dimensions and lower weight, supported on a keel, wooden supports are used

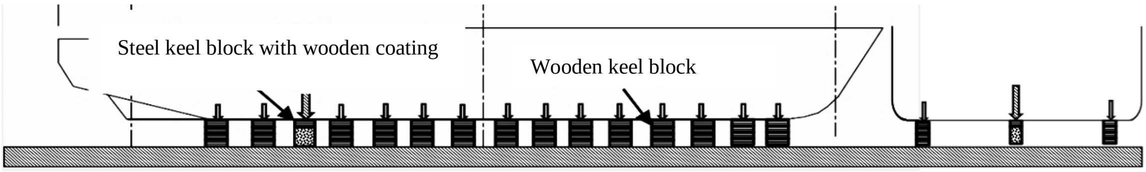

Fig. 8 Various hull pressure on keel blocks of different structure (2)

Using supports of different structure results in formation of stresses in supporting points as presented in **Figure 8** which may lead to dents in the shell plating, and even to permanent deformations of the bottom structure (2),(3).

CONCLUSIONS

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.

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