

Preliminary analysis of proposed ship docking systems for a designed floating dock

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ABSTRACT

In this paper are presented alternative design concepts and their comparative analysis of ship docking systems for a floating dock. The floating dock was designed by a team of Faculty of Ocean Engineering and Ship Technology, Gdańsk University of Technology, within the frame of the ECOLOGICAL DOCK E!2968 project. The presented design solutions differ to each other mainly by the kinds of applied devices: in the first case these are mooring winches and docking cars, whereas in the other – rope warping winches. For both the specified systems a comparative analysis was carried out in which their features, complexity of construction and associated costs were among other accounted for. In the opinion of the authors the presented analysis may help the principal designer of the dock in making choice of a more suitable system.

Keywords : floating dock, shipboard equipment, mooring devices

INTRODUCTION

The basic mooring system of floating dock consists of the following elements :

- ★ mooring winches or docking cars driven by warping winches
- ★ warping capstans
- ★ mooring bollards
- ★ mooring fairleads.

The mooring winches are located at the upper deck ends of both side walls of floating dock. They make it possible to bring a ship in and out the dock. The warping capstans serve for positioning the ship inside the dock. Their number and pulling power depend on size of ships to be docked. For instance in the Gdańsk Shiprepair Yard two floating docks each of 10 000 t carrying capacity (total mass of a docked ship) are in service, on whose each side wall are located, in the case of the first dock, 2 mooring winches and 3 capstans of 60 kN pulling power, and in the second case, 2 mooring winches and

2 capstans of 80 kN pulling power. On the upper deck of both side walls are also located bollards and fairleads which make it possible to handle the mooring ropes. Near the capstans single roller fairleads are installed.

PROPOSED SYSTEMS

I. Design solution based on docking cars

The solution which has been proposed by *Sinus Co.*, is shown in Fig.1. The system is composed of such docking devices as :

- ✦ warping winches of guiding ropes (Fig.3)
- ✦ docking cars (Fig.2)
- ✦ warping capstans (Fig.5)
- ✦ roller fairleads (Fig.4)
- ✦ mooring bollards.

For ship docking operation have been used the docking cars (see item 2 in Fig.1), driven by means of the warping winches (item 3) placed on the safety deck.

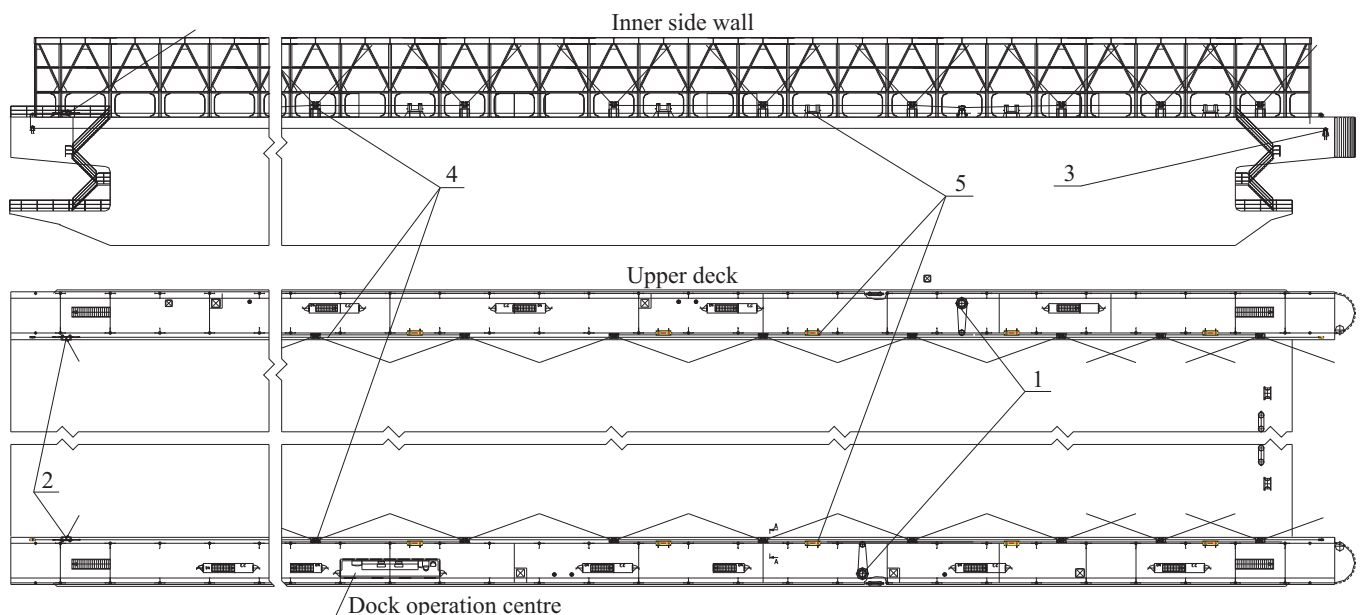


Fig. 1. Variant I. Notation : 1 – capstan, 2 – docking car, 3 – warping winch, 4 – fairlead, 5 – bollard .

Docking the ship is realized with the use of two cars shown in Fig.2 in the position beginning the entire operation. To the cars mooring ropes of the docked ship are fixed. The cars are placed on the leaders attached to both side walls. Driving the cars in question is executed by means of the rope-pulley system and warping winches, shown in detail in Fig.3. The winches of 100 kN pulling power each are located on the safety deck placed beneath the upper deck.

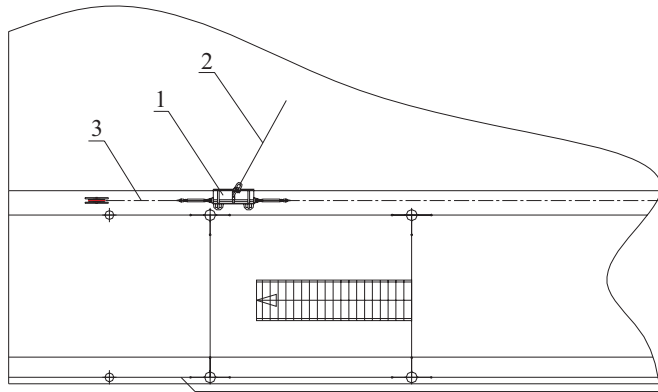


Fig. 2. Initial position of the car on the side wall.

Notation : 1 – docking car, 2 – rope gone out the ship, 3 – guiding rope .

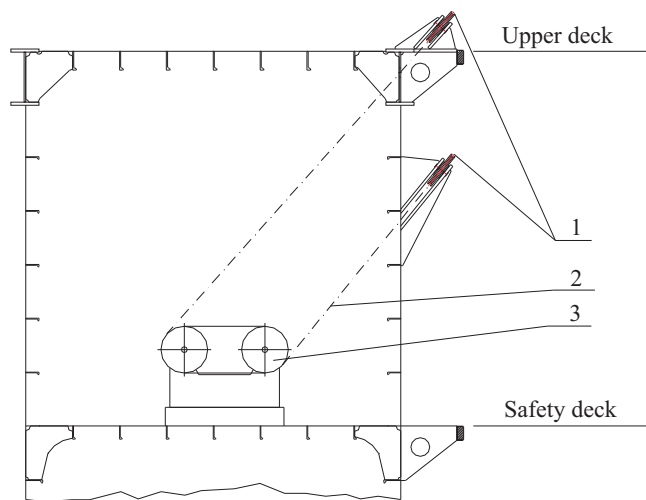


Fig. 3. Location of the warping winch of docking car .

Notation : 1 – guiding rollers, 2 – car guiding rope (shifting the car along the side wall), 3 – warping winch .

A ship to be docked is positioned in the dock's plane of symmetry by using ropes, capstans, special roller fairleads and bollards.

To both sides of docking cars the ends of the guiding ropes are attached by means of Roman bolts. Application of such bolts makes straining the ropes easier. In the considered solution to use the system in question for moving the dock's roof segments is also possible. For such operation the guiding rope is released from the car and then fixed to a special catch pawl of the movable roof segment.

Two capstans are installed on each of the upper decks of both side walls of the dock. The capstans (item 1, Fig.1) are placed near the dock's ends. Their rated pulling power amounts to 80 kN. They are auxiliary devices used for positioning the docked ship (i.e. guiding the ship onto the keel blocks).

The roller fairlead (4) makes it possible to appropriately guide the rope from the capstan either onto the deck of docked ship or the bollards (5) and chocks, and next from them onto the ship.

The applied roller fairleads make it possible to guide the rope in various directions. In Fig.4 an example of guiding the rope is shown. Application of the dismantlable upper rollers

makes it possible to easily translate the rope to other roller fairleads during mooring the docked ship or moving the dock's roof segments.

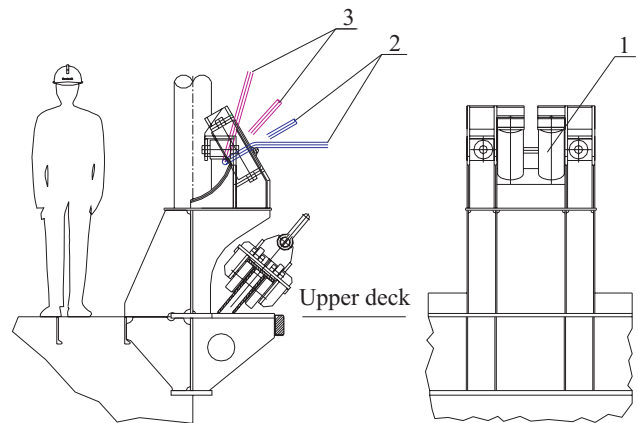


Fig. 4. Roller fairlead which makes it possible to dock the ship as well as to

move the dock's roof segments. Notation : 1 – dismantlable roller, 2 – direction of running the ship docking ropes, 3 – direction of running the roof moving ropes .

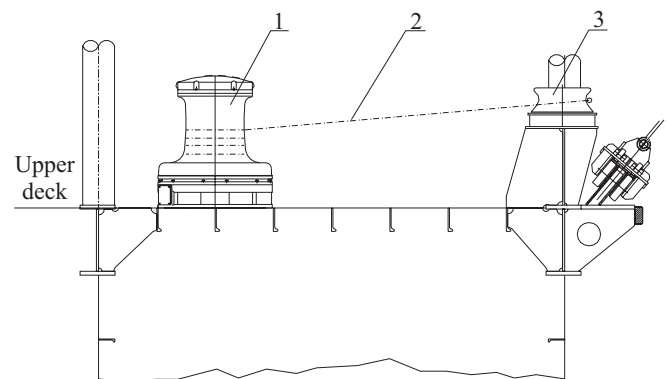


Fig. 5. Auxiliary devices for docking the ship and moving the dock's roof

elements. Notation : 1 – capstan, 2 – rope to moor the dock or to move its roof elements, 3 – directing roller .

It can be observed that the solution in question may fulfill two important function : the docking of the ships and the moving of the dock's roof segments. The operations require to synchronize work of warping winches and appropriate straining the rope. One can consider if to strain the rope by means of the Roman bolts is sufficient. Such function can be better realized by hydraulic stretchers or spring elements.

The described solution is relatively simple and inexpensive. However it requires two cars and two mutually synchronized warping winches to be installed on each of the dock side walls. In the opinion of the authors a weakness of the solution is that in the case of non-uniform strain of the rope by both warping winches some rope slip can occur which may lead to the lack of control over the length of working string. It is associated with the danger of non-uniform distribution of loads in both ropes and – in consequence – skewing the roof segment during its motion.

II. Design solution based on docking winches and four capstans

The solution proposed by the team of Gdańsk University of Technology, is composed of the following docking devices (Fig. 6):

- 4 ship docking winches
- 4 capstans
- roller fairleads (Fig.4)
- bollards.

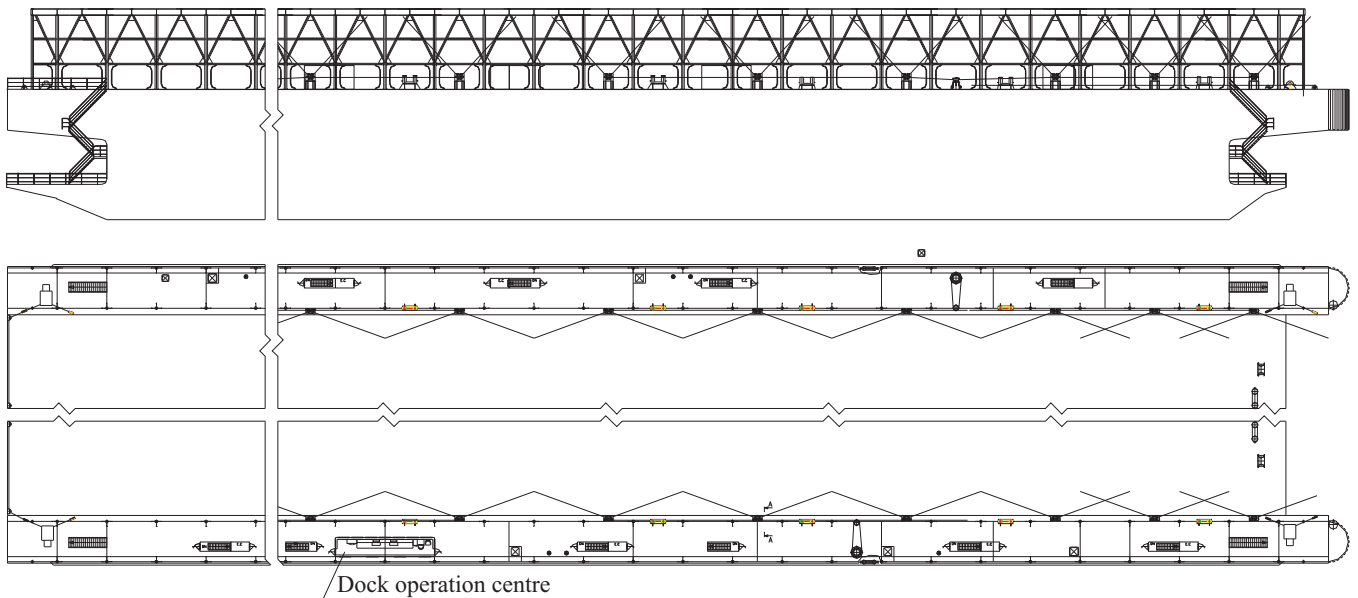


Fig. 6. Variant II

Docking the ship is realized by using two main winches installed in the front part of the dock, namely one on each side wall, and two auxiliary winches located in the rear part of the dock. From the main winches ropes are passed to the ship bow where they are fixed to towing bollards. During 1st docking phase only the main winches are used, and a tug operating behind or alongside the ship secures the operation. 2nd docking phase begins when about 1/3 part of the ship is already towed into the dock. In this phase take part the capstans placed near the dock's end, which help positioning the ship in the dock's plane of symmetry. In the successive phase, ropes are passed from the ship's stern to the auxiliary winches, and the ropes from the capstans situated at the dock's end are transferred to the capstans situated nearer the main winches. Next, the whole ship is towed into the dock.

The solution, like the preceding one, makes it possible to use it also for shifting the roof segments. All four winches installed on the dock must then operate. On each of the side walls two winches are installed, one in the front part, and the other in the rear part. Ropes from the both winches are fixed to the catch point of the roof segment, placed in the mid-length of the segment (see Fig.7). The winch hauling away the rope is set up to work at higher values of parameters, and the winch laying out the rope – to work at lower values of pulling power, so as the difference of the pulling powers were sufficient to overcome resistance to motion of the displaced object. In such case there is a danger of uneven winding the ropes onto the drums of the winches located at both side walls of the dock. For this reason the motion of the displaced object should be continuously controlled.

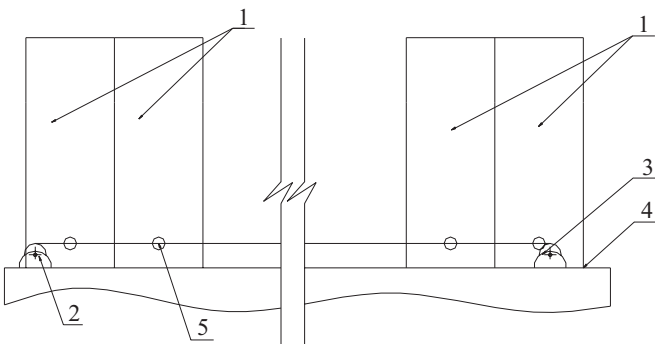


Fig.7. Operation of the winches in the case of moving the dock's roof segments.
Notation : 1 – roof segment, 2 – the winch hauling away the rope, 3 – the winch laying out the rope, 4 – main deck, 5 – rope fixing element .

ASSESSMENT OF WARPING WINCH PARAMETERS

In the *Rules for the classification and construction of floating docks*, Part IV, p. 1.1. [4] concerning general regulations a reference to the *Rules for the classification and construction of sea-going ships* [3] is given, therefore the pulling power of dock mooring winches was estimated by applying the Equipment Number for the largest ship which can be placed in the dock in question.

Table. Main particulars of the largest ship to be docked

Maximum overall length	~170 m
Maximum supported length	156.00 m
Maximum breadth	34 m
Maximum draught	5.8 m
Maximum mass	10 000 t

To estimate the Equipment Number for the largest ship to be docked is possible on the basis of the above given data (according to *Sinus Co.*), hence the breaking strength of towing rope can be determined from the relevant PRS rules (Part III „Hull Equipment”, Tab. 4.1.2) and in consequence to estimate the pulling power of the warping winch intended for docking operations.

The so estimated Equipment Number amounts to 878 [-]. The breaking strength of the towing rope amounting to 518 kN was determined from the above mentioned Tab. 4.1.2.

By making use of the formula for the pulling power of the winch :

$$U = \frac{P_{zr}}{x}$$

where :

- U – winch pulling power [kN]
- P_{zr} – rope breaking strength [kN]
- x – safety factor [-] ,

the following is achieved :

$$U = \frac{518}{3} = 172.67 \text{ [kN]}$$

Therefore the pulling power of the winch should be equal to 173 kN.

CONCLUSIONS

- **Variant I** is relatively inexpensive because of the number and kind of the devices applied to ship docking : these are 4 capstans, 2 warping winches and 2 cars. In the design solution in question a problem associated with ensuring a correct run of winded rope appears, especially if its length of 375 m is taken into account. An advantage of the system is the possibility of ensuring relatively constant speed of rope winding due to constant diameter of winch drum. In the applied drums circumferential grooves are made to improve conditions for frictional coupling of the grooves and rope. However it should be stressed that as a result of the application of the grooves accuracy of keeping constant speed is somewhat decreased as the effective diameter of the rope winding in the drum's groove, decreases along with increasing the load.
- **Variant II** is even simpler and less expensive design solution than the preceding one. However it has a fundamental drawback, namely the necessity of winding the rope around the drum in two layers at least. This results from limited gabarites of the winch. As a result, to ensure uniform guiding the ship into the dock or shifting the dock's roof segment, the control over motion of a displaced object must be made stronger. To ensure relatively uniform conditions for winding the rope on both winches they should be fitted with a rope layer. Possible differences of instantaneous length of ropes on both winches must be currently corrected by manual control of each of the winches.
- The application of the roller fairleads to both the presented variants makes it possible to lead the rope in various di-

rections : towards the docked ship or dock's roof segment (Fig.4), and the application of the easily dismantlable upper rollers greatly facilitates necessary transferring the rope from one fairlead to another.

- In the above presented design solutions the capstans fulfill an auxiliary role – they help maintaining rectilinearity of guiding the ship during docking operation.
- Both the discussed variants do not guarantee maintaining the same speed of hauling away or winding the ropes on both dock's side walls, therefore appropriate measuring instruments for controlling motions of a displaced object should be provided to ensure correct execution of the operations in question.

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