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SIMULATION OF BALLAST TRANSFER FOR PONTOONS

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Abstract: *The article is aiming to compare the efficiency in time of the draft balance of a RO-RO pontoon, the adjustment of the draft being done with a pump or a compressor. Currently, pontoons are being built with ballast tanks and the loading/unloading system uses a pump that deals with this. This comparison will be made in the operation of ballasting, de-ballasting, and transfer. All operations simulations will be performed using PipeFlow software in order to compare and assess seawater tanks, tubing, pressures, flows etc. The results of the research provide information for improving the operational efficiency of the use of the port infrastructure during the loading/unloading operations that involve the existence of a pontoon.*

Key words: *Ballast system, Pump, Compressor, PipeFlow, Computer Simulation.*

1. INTRODUCTION

Floating pontoons are public access structures which ensure the connection between the land and the sea, although the floating pontoons are supervised by staff. [1].

The types of pontoons addressed in this work are RO-RO pontoons. They are used for loading/unloading vehicles on RO-RO[1] type ships. Unlike ships, which can only be efficiently operated at small heel angles, floating structures can have their stability influenced by factors such as the shape, width of the submerged portion, as well as the weight and draft of the object. [2]

The pontoon approached as case study is a pontoon with a built-in draft regulation system. It helps to align the pontoon to the draft of RO-RO type ships for increased efficiency when transporting vehicles from the ship to land and/or vice versa [3]. For the draft adjustment operation, two types of systems can be used:

- with the ballast pump;
- with the compressor.

Floating pontoons usually have a ballast tank system to compensate for the differences that occur with the ships draft but this system requires accurate and reliable information about the liquid ballast distribution as an input parameter to provide effective draft compensation. Therefore, measuring the draft is one of the most important tasks in its exploitation [4].

Ballast pumps are used for pumping fresh/sea water from ballast tanks during loading, unloading and balancing of the floating structure. The mechanical system that takes seawater into or from the marine vehicle, such as ballast pumps, should be designed to filter solid particles that have adverse effects on rapid system failure.

The principle of operation is similar to that of a floating dock which is a submerged structure that allows a ship to enter and dock, and it can later be raised to elevate the ship above the water level for repairs or maintenance [5].

Nonetheless, transferring ballast water between different aquatic environments can lead to the transportation of Harmful Aquatic

[1] RO-RO Vessel - Roll-on/roll-off vessels are specifically designed for transporting wheeled cargo, which includes automobiles, buses, trucks, motorcycles, and trailers. [13]

Organisms and Pathogens (HAOP) [6]. Species transferred, which may encompass bacteria, microbes, small invertebrates, eggs, cysts, and larvae of diverse species, could endure and establish reproductive populations within the recipient environment. This can lead to invasiveness, competition with native species, and exponential growth, resulting in pest infestations [7].

Ballast and de-ballast operations on floating pontoons involve filling, emptying and transferring water to achieve the required stability and draft for the pontoon. The mode of operation of ballast pumps is based on valve regulation, which can be operated either manually/hydraulic or automatic. [8]

In the case of compressors, air compression is widely used to support industrial manufacturing processes due to its ease of use, practicality and cleanliness. However, the efficiency of compressed air systems is often very low. Typically, for air tools, only 10-15% of the energy consumption is converted into useful work. Despite these inefficiencies, even though energy efficiency measures for compressed air systems normally offer more opportunities to save energy and energy costs, in general less attention has been paid to them incurred in compressed air systems [9]. By introducing the compressor as a ballast/ de-ballast and ballast transfer system, it can be analyzed with the existing solution with a ballast pump and compared to it.

In this regard, it should be mentioned that an additional tank with a capacity at least equal to the sum of the existing tanks on the pontoon must be added. This is necessary due to the fact that the compressor is not designed as a vacuum system, thus ballast cannot be suctioned into the related tanks.

The purpose of comparing the two installations is to determine the time efficiency of ballasting/ de-ballasting and ballast transfer operations. By reducing the draft adjustment time, the waiting time for RO-RO vessels that stationary in the harbor to be able to load or unload vehicles is also reduced. Waiting in the queue leads to fuel consumption because at least one diesel-generator is in operation. Another purpose of introducing a system with the potential to improve the draft adjustment time is to not use the existing ballast pumps on the ship because any electric motor in operation leads to an increase in fuel consumption of the existing diesel generators on the ship.

2. ADJUSTING THE DRAFT OF A RO-RO PONTOON

The basic structure of the pontoon consists of three tanks of different volumes as follows in the Table 1:

Table 1

Capacity of the system's tanks

Tank	Tank capacity [m^3]
Tk No.1	75
Tk No.2	100
Tk No.3	60

The layout of the tanks is represented in the Fig.1:

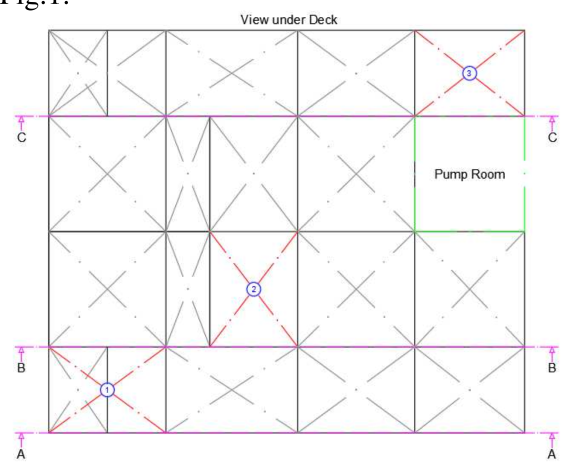

Fig.1. Arrangement of ballast tanks

Views of the tanks "Tk No.1", "Tk No.2" and "Tk. No3" can be observed in the Fig.2:

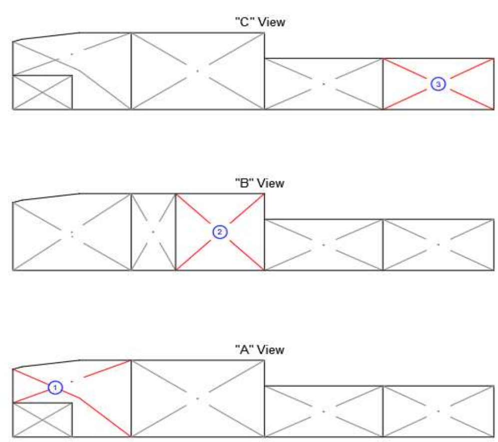

Fig.2. Sides view of tanks

In the case of using the compressor, an additional tank of a quantity at least equal to the sum of the existing tanks in the structure of the pontoon must be inserted. This additional tank will be located on the dock in order not to influence the stability and draft of the pontoon. The placement can be seen in Fig.3:

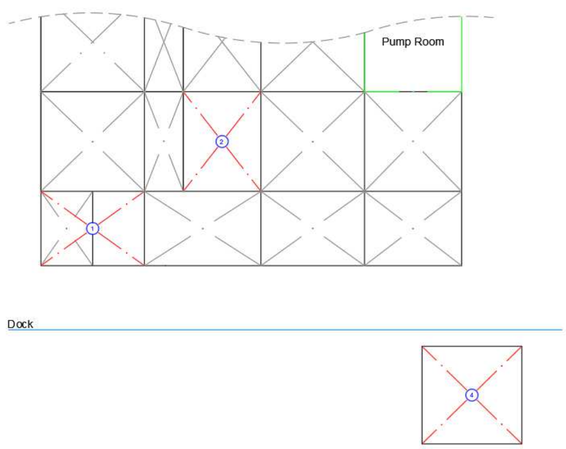

Fig.3. Arrangement of ballast tanks in case of using compressor

The arrangement of the tanks in Fig.1 does not change after adding the additional tank "Tk No.4" from Fig.3. The "Tk No.4" tank will have a capacity of 235 m^3. Consequently, in the case of the method of regulating the draft using the compressor, Table 2 is given:

Table 2

Tank capacity in case of using compressor

Tank	Tank capacity [m^3]
Tk No.1	75
Tk No.2	100
Tk No.3	60
Tk No.4	235

It should be mentioned that the pump and the compressor are of equal power, respectively 18.5 kW.

2.1 Ballast installation using the pump

There are two pumps at the base of the ballast installation, usually one is on standby, therefore only one pump can be considered by the authors and a maximum consumption of 18.5kW [10]. The model of the chosen pump is INM 100-315 [11] thus the nominal pump flow rate is 175 m^3/h. Electrically controlled valves and a DN100 piping were assigned to this system in order to be functional. During the unloading operation, the fluid goes through a reduction from DN100 to DN80. In Fig.4 is illustrated the ballast installation using the pump.

Based on the P&ID (Piping & Instrumentation Diagrams) of the installation that uses the pump, the diagram could be made in PipeFlow. To simulate the overboard ballasting operation in the software, a tank that simulates the sea was used (the one on the right, without numerical indication). The simulated installation is represented in Fig.5.

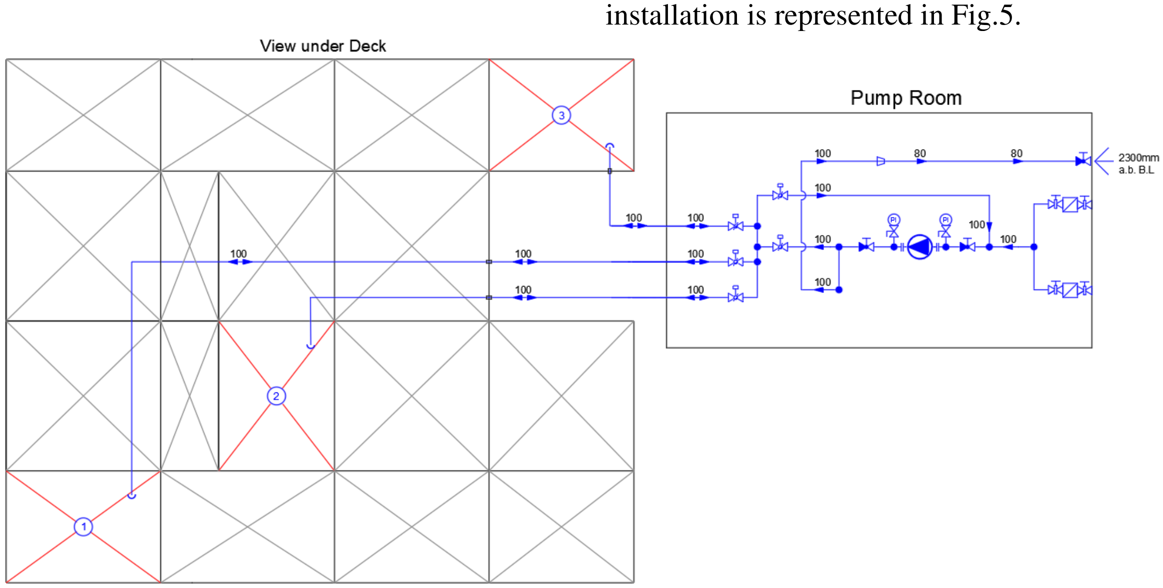

Fig.4. P&ID in case of using one pump

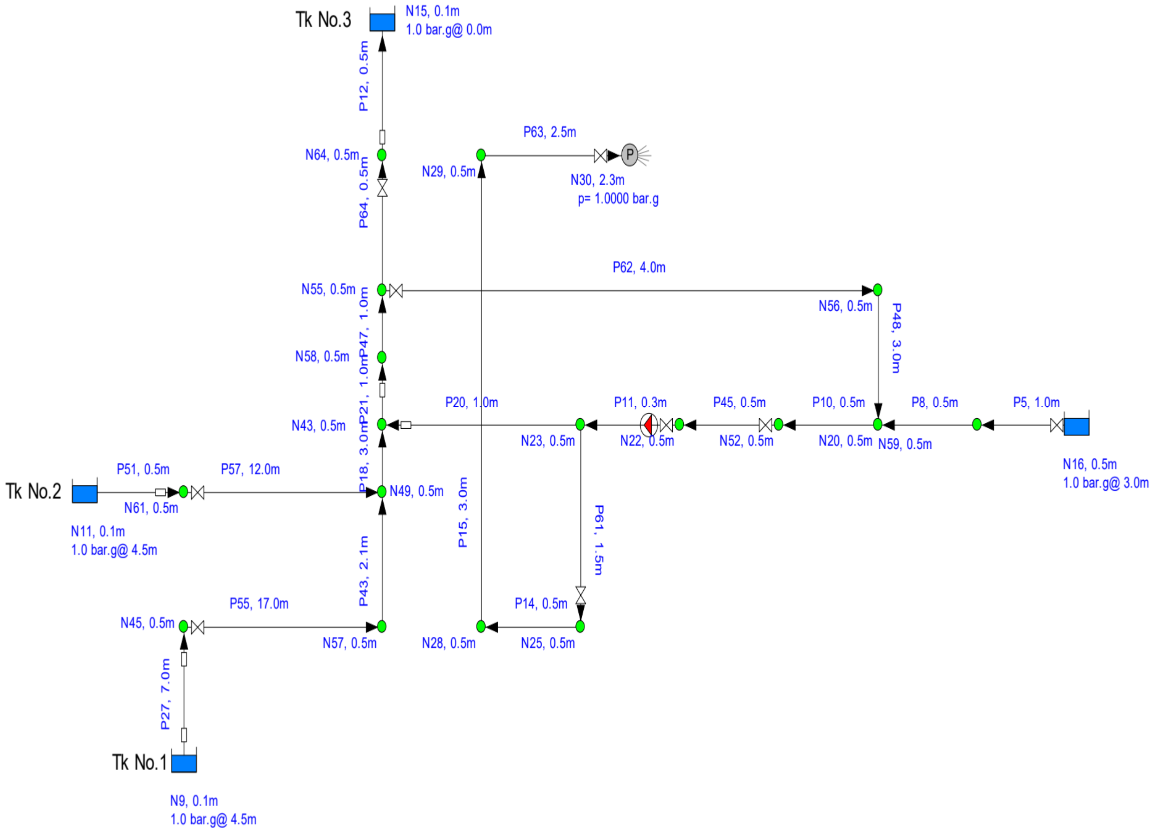

Fig.5. P&ID in case of using one pump in PipeFlow

After carrying out multiple simulations regarding the ballasting and de-ballasting of each tank, presenting an example of the simulation in Fig.6, the authors can determine the times for performing each maneuver.

These, the time parameters, are present in Table 3 for the ballasting operation and in Table 4 for the de-ballasting operation.

Table 3

Ballast time from 0% to 100% of tanks with pump

Tank	Tank capacity [m^3]	Flow [m^3/h]	Time [h]
Tk No.1	75	181.949	0.412
Tk No.2	100	190.640	0.525
Tk No.3	60	196.127	0.306

Table 4

De-ballast time from 100% to 0% of tanks with pump

Tank	Tank capacity [m^3]	Flow [m^3/h]	Time [h]
Tk No.1	75	133.694	0.561
Tk No.2	100	138.339	0.723
Tk No.3	60	140.456	0.427

The case of transfer between tanks is possible, but the flow with which the tank will be filled will be very small because the pump will recirculate the fluid taken from the tank from which the extraction is done.

This can be observed according to the simulations in Fig.7, where the pump has a flow of 190.270 m^3/h and at the entrance to the tank one of 33.747 m^3/h, which will require a transfer time of 1.778 h.

For the transfer operation between tanks, it can be considered more efficient to de-ballast the "Tk No.1" tank in a proportion of 80% to overboard, which means 60 m^3, and to ballast the "Tk No.3" tank from the sea.

To carry out these operations, a time of 0.755 h is required, of which 0.449 h is required for the de-ballasting operation and 0.306 h for the ballasting operation.

It is taken into account that the "Tk No.1" tank is not emptying completely because there are still 15 m^3 remaining, representing a 20% load of the tank. This aspect can be useful in certain cases of draft regulation.

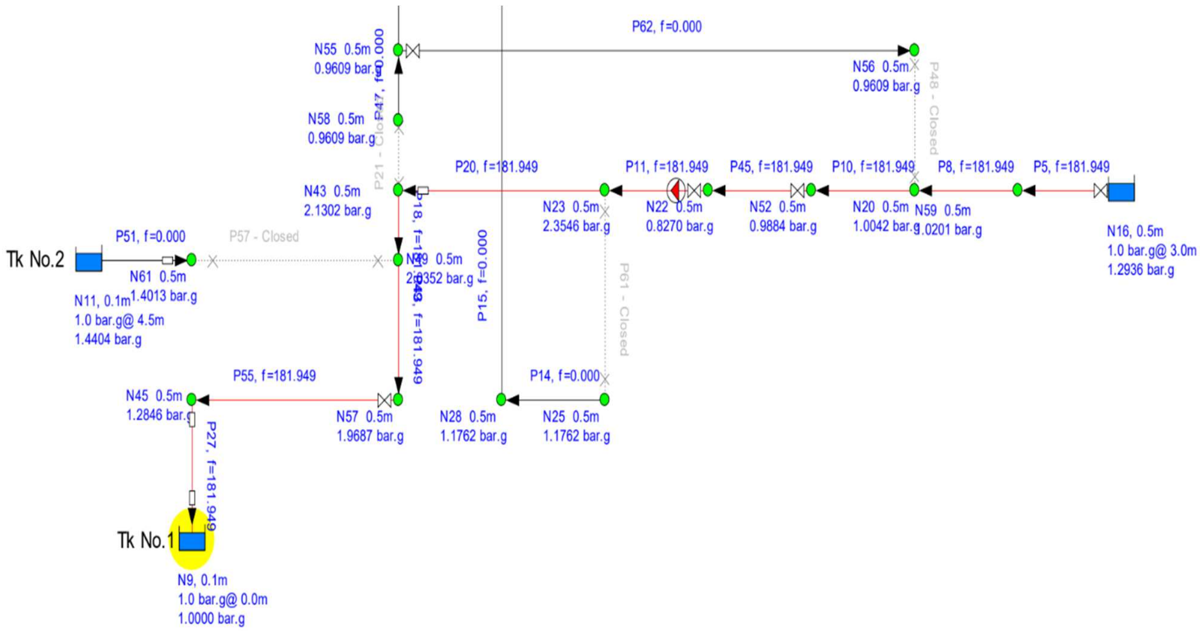

Fig.6. Simulation of ballasting "Tk No.1" in PipeFlow using pump

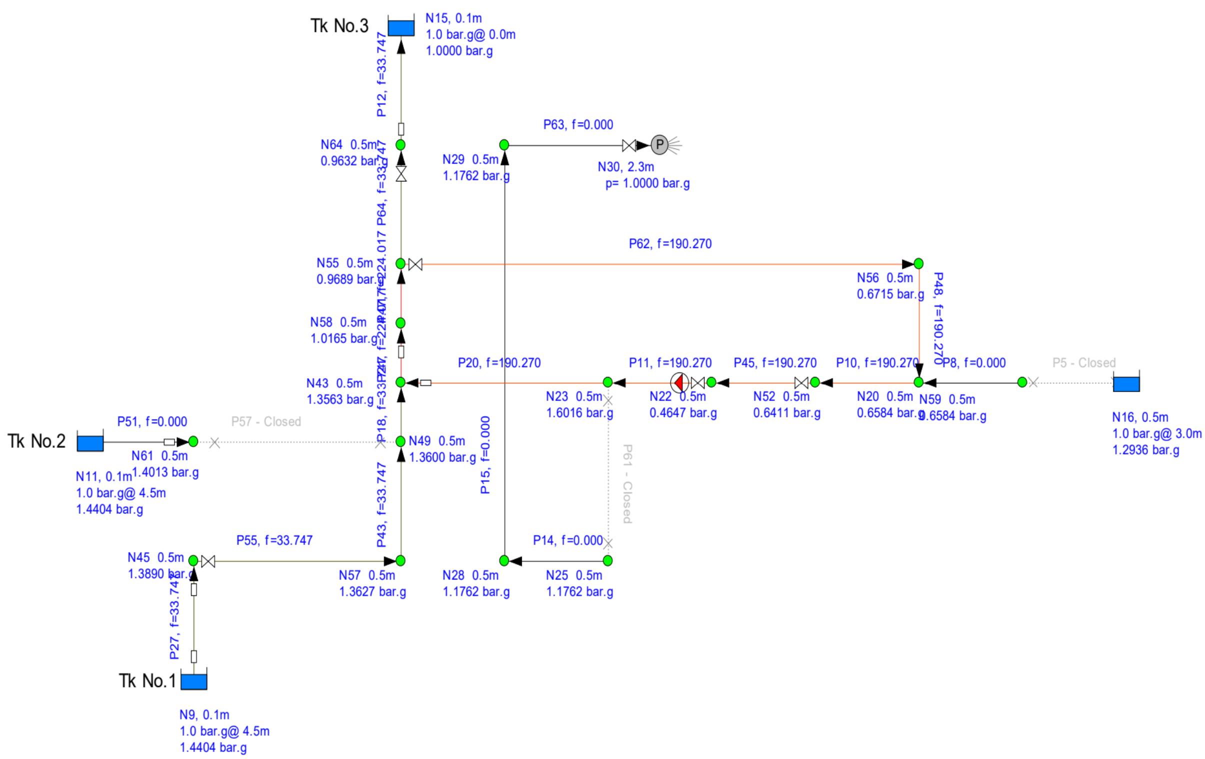

Fig.7. Simulation of transfer operation from "Tk No.1" to "Tk No.3" using pump

2.2 Ballast installation using the compressor

At the ballast installation, which has a compressor as the equipment to set the fluid in motion, the structure of the piping is changed by adding the compressed air installation that includes electrically actuated valves and 10 bar safety valves. For this system the authors will be using a DSR18 type compressor [12]. The compressor will be mounted outside the pontoon, on the "Tk No.4" tank.

Based on the P&ID illustrated in Fig.8 of the installation that uses the compressor could be diagrammed in PipeFlow, Fig.9.

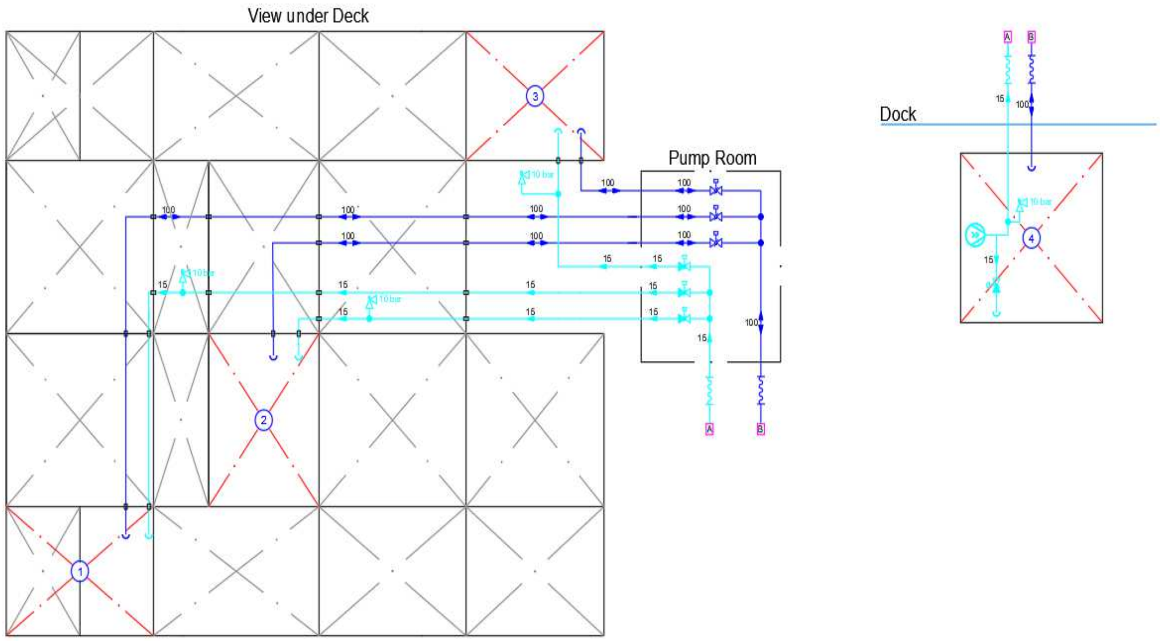

Fig.8. P&ID in case of using compressor

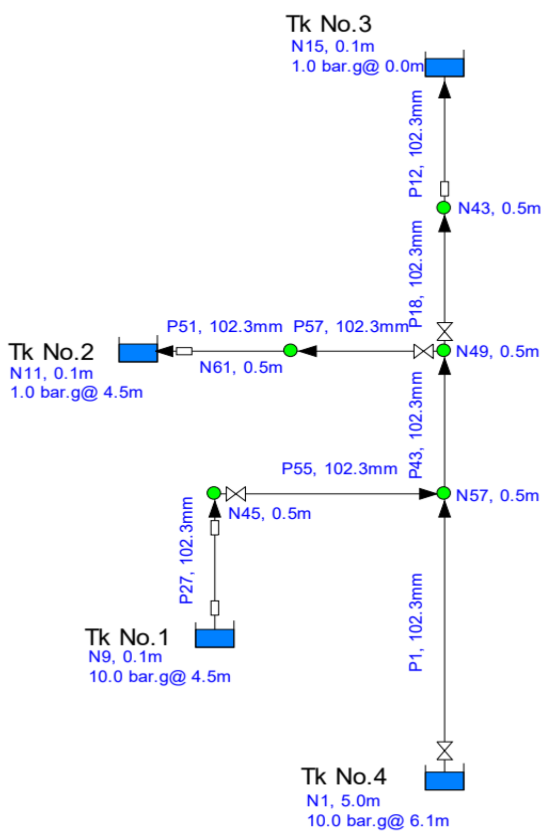

Fig.9. P&ID in case of using compressor in PipeFlow

Following the simulations of ballasting from 0% to 100% load and de-ballasting from 100% to 0% load, time parameters were obtained for these operations. These are present in Table 5 for the ballasting operation and in Table 6 for the de-ballasting operation.

Table 5

Ballast time from 0% to 100% of tanks with compressor

Tank	Tank capacity [m^3]	Flow [m^3/h]	Time [h]
Tk No.1	75	392.772	0.191
Tk No.2	100	428.311	0.233
Tk No.3	60	453.410	0.132

Table 6

De-ballast time from 100% to 0% of tanks with compressor

Tank	Tank capacity [m^3]	Flow [m^3/h]	Time [h]
Tk No.1	75	357.520	0.210
Tk No.2	100	389.901	0.256
Tk No.3	60	409.118	0.147

The transfer procedure using the compressor is not the same as when the pump is used. As far as the compressor is concerned, this operation can be performed without any loss or through the procedure of de-ballasting and then ballasting the desired tank. In Fig.10 is illustrated the transfer of ballast from the "Tk No.1" tank to the "Tk No.3" tank. In this simulation, a flow rate of 438.484 m^3/h can be observed, which is equivalent to a time of 0.137 h for this operation. However, even during this operation, the "Tk No.1" tank remains loaded to the extent of 20%.

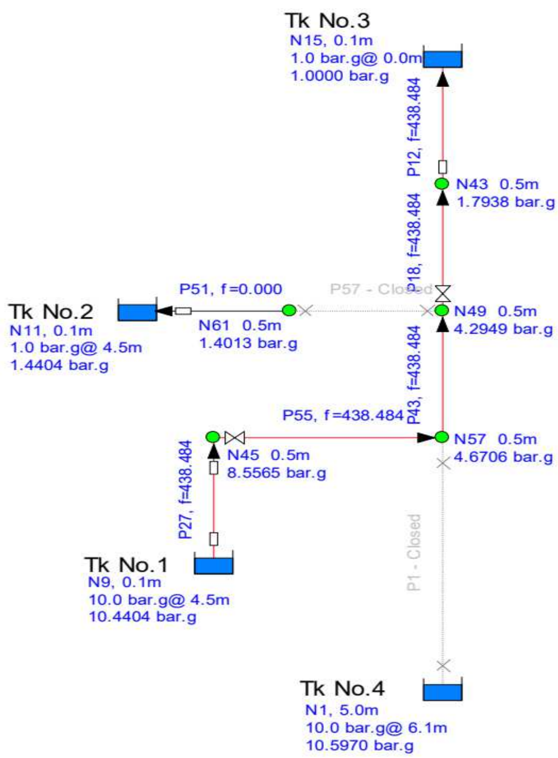

Fig.10 Simulation of transfer operation from "Tk No.1" to "Tk No.3" using compressor

3. COMPARATIVE ANALYSIS OF THE TWO METHODS OF ADJUSTING THE DRAFT

Following the data from the previous chapter, it can be demonstrated that the use of the compressor is more efficient than the use of the pump. As a result, comparison data of the flows of the two methods are presented in Fig.11 for the ballasting operation and in Fig.12 for de-ballasting operation:

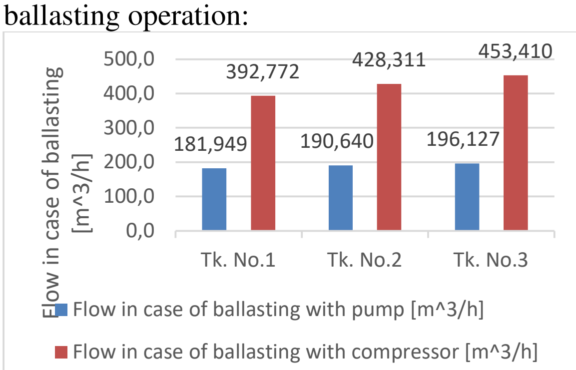

Fig.11 Flow rate in case of ballasting using both methods

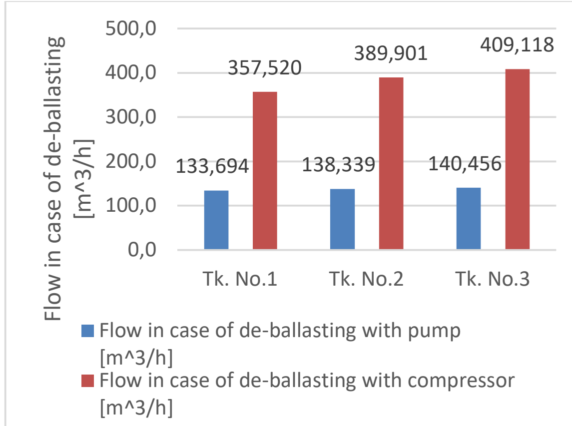

Fig.12 Flow rate in case of de-ballasting using both methods

Following the simulations, the flow rates were extracted when using the pump and the compressor for the ballasting/de-ballasting operations, one time graph can be considered for each operation, Fig.13 and Fig.14.

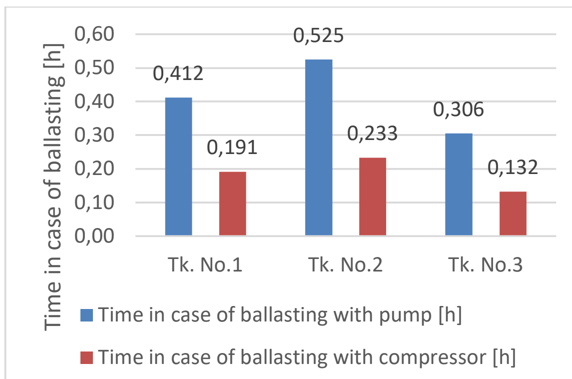

Fig.13 Time in case of ballasting using both methods

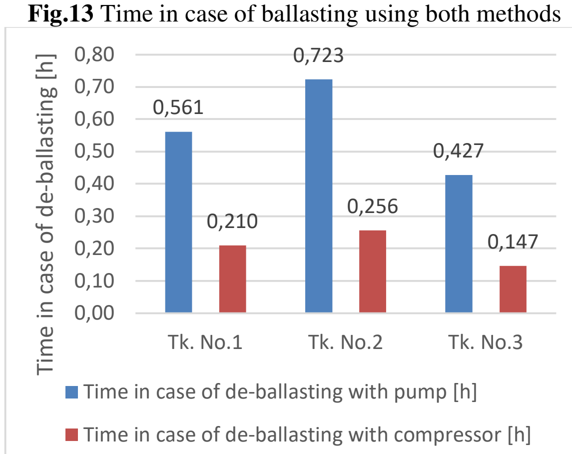

Fig.14 Time in case of de-ballasting using both methods

Based on the execution times of the operations, using the compressor for ballasting results in a 223.91% higher time efficiency compared to using the pump, while for unloading, the compressor offers a 280.18% higher efficiency. Overall, the compressor is more efficient with an average of 252.04% compared to the pump.

Regarding the transfer operation from the "Tk No.1" tank to the "Tk No.3" tank, the case addressed in terms of the use of both methods, it can be seen that the handling time after using the pump is 5.51 times higher than in the case of using the compressor as you can see in Fig.15.

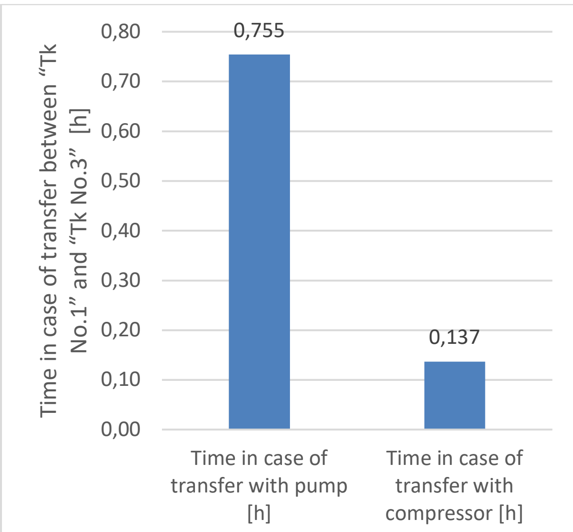

Fig.15 Time in case of transfer between "Tk No.1" and "Tk No.3" using both methods

To confirm the fact that the compressor is more efficient when speaking of the transfer operation between tanks, another transfer between tanks "Tk No.3" and "Tk No.2" will be simulated. The tank "Tk No.3" is the one from which ballast will be extracted. This instance was chosen because the "Tk No.2" tank has a larger capacity with 40 m^3 more than "Tk No.3" tank. Regarding the ballast pump in use, there is an unloading time of 0.427 h for tank "Tk No.3" and a time of 0.525 h for ballasting tank "Tk No.2". This means the total time for this transfer is 0.952 h.

In terms of the compressor, the first 60 m^3 will be extracted from the "Tk No.3" tank, which creates a flow rate of 516.401 m^3/h, which means a time of 0.116 h. The remaining 40 m^3 missing from the tank "Tk No.2" will be included from the tank "Tk No.4". At a flow rate of 389.901 m^3/h a transfer time will be 0.103 h. In total, the transfer time between these two tanks is 0.219 h. Graph present in Fig.16 is a result of comparing these two methods.

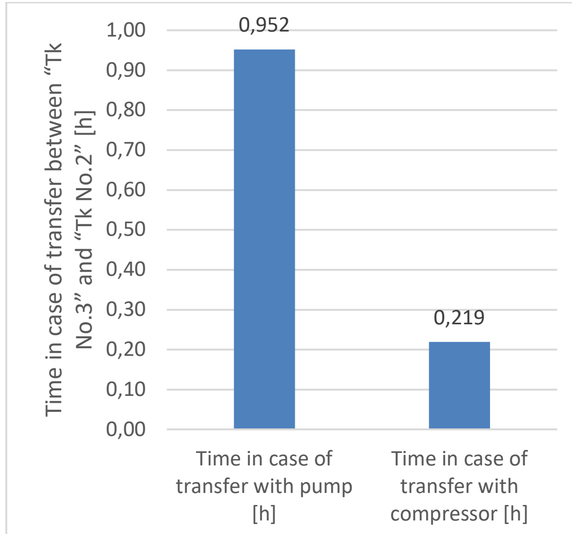

Fig.16 Time in case of transfer between "Tk No.3" and "Tk No.2" using both methods

According to the data presented concerning the ballast transfer from the "Tk No.3" tank to the "Tk No.2" tank, the use of the compressor is 4.34 times more efficient than the use of the pump.

For the transfer operation, these two cases presented above were chosen from the six possible ones, because they are unfavorable cases for both installations.

When the compressor is used, this increased efficiency also attracts disadvantages in terms of the construction and integration of the system, compared to the construction and integration the system that uses pumps:

- In addition to the ballast installation, it requires the introduction of the compressed air installation;
- Recalculation and resizing of the tank structure to be resistant to a pressure of at least 10 bar;
- Recalculation and resizing of the ballast piping, because at a maximum flow rate of approximately 500 m^3/h, the fluid movement speed increases, which leads to rapid damage to the interior of the pipes;
- Introduction of an additional tank with a capacity at least equal to the sum of all

existing tanks in the construction of the pontoon;

- Extension of the ballast piping to the dock for the connection with the "Tk No.4" tank.

All the causes presented above have a weak point from a financial point of view when implementing this system, but this may be compensated during the long exploitation of this system:

- Reducing the waiting time of RO-RO type ships in the harbor, which leads to less fuel consumption on board of the ship;
- Adjusting the draft of the pontoon and not of the ships that dock for loading/unloading operations, which leads to less fuel consumption on board the ships;
- Increasing the number of loading/unloading vehicles, which leads to an increase in receipts from vehicle transits.
- Reducing the operations performed by the captain to stabilize the ship by compensation given by the pontoon.

4. CONCLUSION

To summarize both presented systems are not to be neglected, each having strengths and weaknesses, a general perspective of the duration required for the ballasting and de-ballasting operation is given in Fig.17.

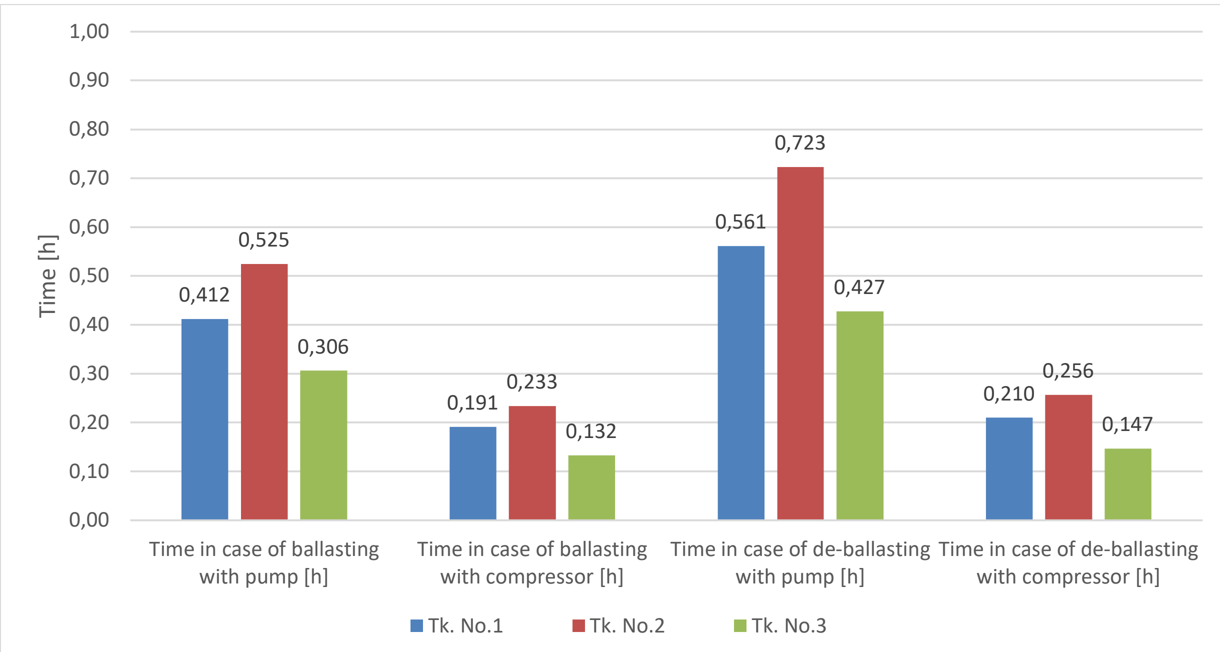

Fig.17 An overview of the times required for ballasting and de-ballasting operation

In terms of ballasting using the pump, it has smaller constructions for implementation on board the pontoon, but at the same time it takes more time for all possible operations to adjust the draft. In addition, the ballast installation does not need to be modified to support high flows.

In the case of the compressor used to perform draft adjustment maneuvers, the construction and implementation costs are higher compared to the pump. The implementation of a compressed air installation can be a rather significant minus compared to the installation that uses the pump. At the same time, it offers a time efficiency advantage when adjusting the draft compared to the ballast pump. On average, it is 223.907% more efficient during ballasting operations and 280.180% more efficient during de-ballasting operations, resulting in an overall average efficiency increase of 252.04%.

These two methods can be used for any type of pontoon and the type of system chosen depends on the draft adjustment time.

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Simularea transferului de balast pentru pontoane

In prezentul articol vom compara eficienta in timp a reglării pescajului unui ponton RO-RO, ajustarea pescajului făcându-se cu o pompa sau cu un compresor. In prezent se construiesc pontoane care au în componenta tancuri de balast, iar sistemul de încărcare/descărcare utilizează o pompa. Aceasta comparație se va face la operațiunile de balastare, debalastare, si de transfer. Toate simulările de operațiuni vor fi efectuate cu ajutorul software-ului PipeFlow cu ajutorul căruia se vor simula tancurile de apa de mare, tubulatura, presiuni, debite etc. Rezultatele cercetării oferă informații pentru îmbunătățirea eficientei operaționale a utilizării infrastructurii portuare pe durata operațiunilor de încărcare/descărcare ce implica existenta unui ponton.

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