SIMULATIONS PERFORMED TO REFLOAT A GROUNDED SHIP

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ABSTRACT

Over the years, there has been an increased concern in the shipping industry about general risk issues. The consequence of this trend is that whenever a catastrophic accident occurs amongst the ships belonging to the worldwide fleet - and receives media coverage - there is an immediate political and public demand for actions to prevent the same type of catastrophe in the future. Many of the past improvements in safety of marine structure have been triggered by disasters but there is a change in this trend. In line of these aspects, it is clear that rational procedures for evaluating the consequences of accidental loads are highly desirable, not to say necessary.

In this paper I am researching the conditions to refloat a grounded ship by using only the means available onboard.

Keywords: *shipping industry, ship, simulation, grounded, refloat.*

1. INTRODUCTION

During maritime transport it happens many times for ships to go aground. There are various causes for this, combining usually human error with unfavourable meteorological conditions. In most cases, crews try and usually succeed to refloat the ship by her own means. The procedure is a relatively simple one consisting of moving weights from bow to stern if possible and putting the main engine astern in different rudder angles.

Our research emphasizes the fact that the operations for refloating a grounded ship are time-critical and environmental conditions may improve or worsen with time, but the condition of a grounded ship steadily deteriorates. The first manoeuvre taken into consideration by our research to be applied is represented by the attempt of refloating the ship by using the means present onboard (ship's own means of propulsions and different angles of the rudder).

These are the fastest manoeuvres available onboard and in the same time, they are the cheapest ones. The longer the ship remains in a grounded position, the higher are the possibilities for the ship to suffer severe damages and a pollution event to occur. In this paper, I am trying to analyse the possibility of refloating a ship by using her own means of propulsion, namely her main engine, in combination with rudder's different angles. For this purpose, I have performed several simulations using TransasNavi Trainer 5000 Simulator and CAE ANSYS12.1.

The simulation performed on TransasNavi Trainer 5000 Simulator presents a combination of refloating methods: using the main engine in different levels and directions of speed with rudder's different angles in order to reduce the bow draft and thus the pressure exerted by the ship on the sea bottom.

The simulation performed on CAE ANSYS12.1 presents the study of the effect that manoeuvres have when refloating a ship by her own means on the ship's structure, specifically in order to emphasise the limit functioning regimes which may be approached by the ship's crew without endangering the ship's structural integrity.

2. SIMULATIONS ON TRANSAS NAVI TRAINER 5000

During the simulation session, using Transas Navi Trainer 5000 simulator, we've tried to analyse the possibility of refloating a ship by using her own means of propulsion, namely her main engine.

The ship, with her main characteristics and dimensions, is presented below, a LNG (Liquefied Natural Gas), Figure 1, fully loaded and she runs aground on an argillaceous bottom, where the water depth is decreasing significantly.

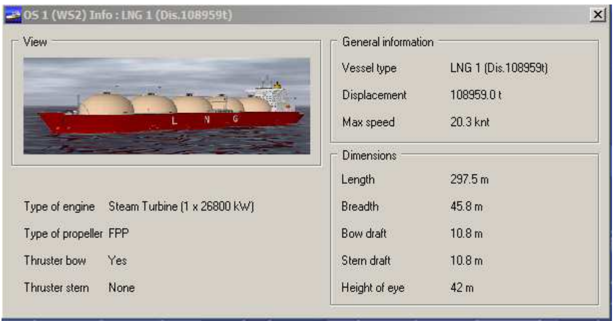


Figure 1 Main characteristics and dimensions of the ship used for simulations

The detailed actions taken to refloat the grounded ship only by using her main engine are presented in the paragraphs below.

During the simulations, I have selected a series of pre-set parameters, like:

- bow/stern drafts
- transversal/longitudinal speeds
- vertical and longitudinal forces
- rolling moment, pitching moment, lateral moment

Their variation for different situations of refloating attempts was followed as in figure 2.

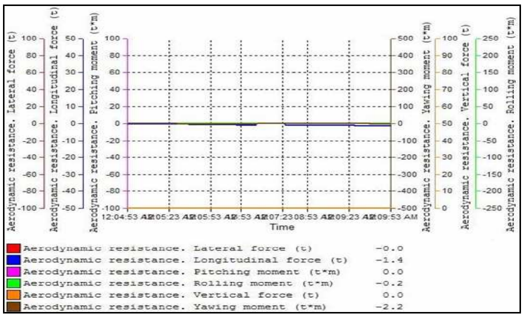


Figure 2 Values of parameters selected for the analysis

During the simulation, it is presented the ship's movement towards the area where the grounding event is going to take place. The water depth decreases gradually, and initially, in deep water, the ship maintains its course but suddenly, due to a decreasing depth and shallow water influence, the ship's course has a deflection towards one of the boards, in this case towards portside.

The bottom of the sea chosen for the grounding event is an argillaceous one and it implicates one of the worst situations for a ship to ground on, because it is very hard for the ship to recover its floatability and to reinstate its floating status due to argil's density and the fact that it is very adherent. During the simulation sessions it will be noticed that, in spite of all efforts, the ship does not manage to refloat itself by using her own means of propulsion and manoeuvring. During the simulation sessions the engine was used up to 'full ahead' and 'full astern' and the rudder was sequentially used from 'hard to port' to 'hard to starboard'.

A series of parameters regarding elements of aerodynamic resistance have been selected. Initially, the influence of surface wind was not taken into consideration and so, the values of the parameters seem to be influenced only by the lateral force and longitudinal forces created due to the existence of shallow waters that push the ship away from its course.

Taking into consideration modification of wind force value, for the beginning Beaufort force 4 – 5 and then Beaufort force 6 (Fig. 3), it can be noticed a significant modification of parameters' values chosen for the study inside this simulation. It can be noticed a significant growth of lateral force moment and rolling moment, values that have a certain influence over ship's grounding; besides grounding speed, lateral pushing force (on the horizontal) and rolling pushing force (on the vertical) are also applied.

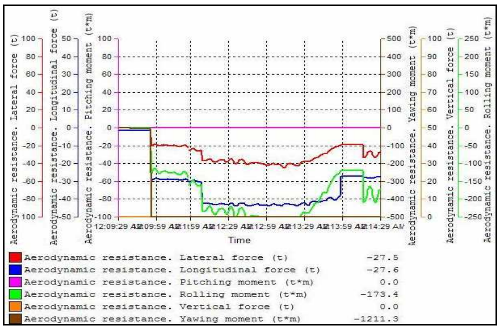


Figure 3 Modification of parameters' values selected depending on wind force (6 Beaufort)

During the simulation, it can be noticed that the parameters' values reach the value of almost zero, and the only one that still affects the ship is the lateral force moment, all the other parameters have small values in comparison with the maximum negative and positive values they can reach.

Further on, it can be observed the variation of lateral force moment for the grounded ship from minus to plus, practically the ship rotates around a gyration point (we will be able to notice this in the second and third simulation).

During the simulation there is an attempt to refloat the ship by using the main engine on 'full astern' (figure 4).

It can be noticed the vector of the ship's direction oriented backwards and the estimation of future positions of the ship, meaning ship's orientation.

Also, it can be noticed the ship's intention to move to portside, practically speaking there is a lateral deflection of the stern but the bow maintains itself approximately on the same direction, and this indicates that the ship yaws, pivots around a point situated from the centre of the ship to the bow. It is a classic situation when the ship grounds with the bow, with more than half of its total length, and the stern remains in water deep enough so that the ship can use its engine and rudder in order to refloat herself.

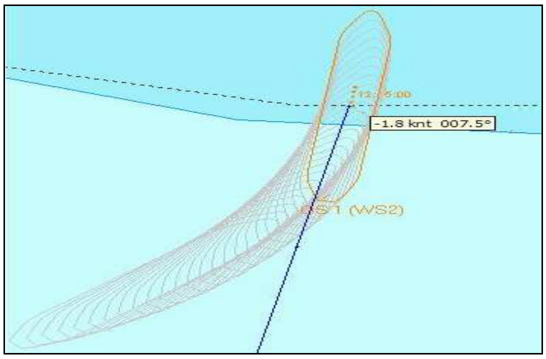


Figure 4 The attempt to refloat the ship with the engine on 'full astern'

During the attempt of refloating the ship, it can be observed a rather small variation of values of lateral force moment, from negative to positive values, which indicates modification of ship's bow orientation (horizontal movements portside-starboard side) and modification of values of pitching moment from -40 to zero (vertical movement on longitudinal axis) which indicates bow's and stern's movement up and down around an axis situated in the new ship's centre of gravity, a centre that appeared as a consequence of grounding.

Further on, the simulation presents the attempts to refloat the ship in that particular case when environment's external conditions (wind, wave and current) do not influence the grounded ship.

The ship is grounded approximately 50-55% towards the bow area, and the stern remains in water deep enough so that the ship can use the main engine, the rudder and the propeller.

In figure 5 it can be observed the speed's vector oriented backwards. The engine is 'astern' and the rudder is amidships. The ship has a rotation movement around the gyration point and also it can be noticed that the stern tends to move backwards and to portside.

When inversing the sail on opposite tack, from 'full astern' to 'full ahead', it can be noticed a rather small movement of forwarding, ahead and astern without managing to shove off from the argillaceous soil.

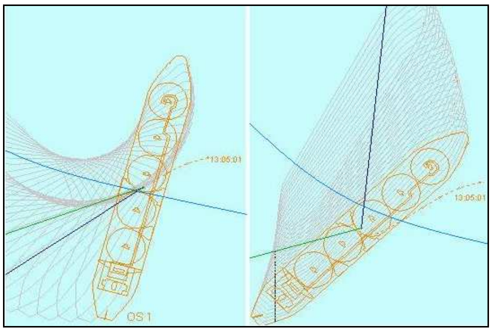


Figure 5 The attempt to refloat the ship with engine ahead – astern

Values of selected parameters remain at a minimum value, the only value that has significant variations is the vertical force of hydrodynamic resistance, a force that reaches the maximum value for a period of time and then decreases, afterwards increasing again, maintaining its' high value.

There is a ship's intention to move towards portside, on its' total length and afterwards it can be noticed that the ship's bow has the tendency to move towards portside, which means that the stern moves towards starboard side.

Taking into consideration the two combined movements of the ship in which the ship's stern moves to portside and the one in which the ship's stern tends to move to starboard side, it can be concluded that the ship gyrates, moves on a circular arc around the pivot point.

The attempts to refloat the ship by using the engine ahead-astern were not successful, although the ship's rotation movement (on the circular arc with a radius starting from the pivot point) creates a freeing area in the argillaceous soil and thus the ship should get out from the grounding zone when the engine is being used 'astern'.

Further on, there is an attempt to shove off the ship by increasing the main engine's maximum revolutions when using it 'astern' to values higher than the maximum permissible ones but the ship continues its gyration movement to starboard side (the bow) and portside (the stern), Figure 6. In the figure it can be observed the movement vector oriented backwards.

When using the engine 'ahead', the main engine cannot be used with maximum revolutions because there is a high risk for the ship to enter even deeper in the argillaceous soil. We can observe the ship's intentions to align almost parallel with the fathom line that indicates the area's minimum depth and the effect caused by the rudder's position (to portside and to starboard side) is not a positive effect.

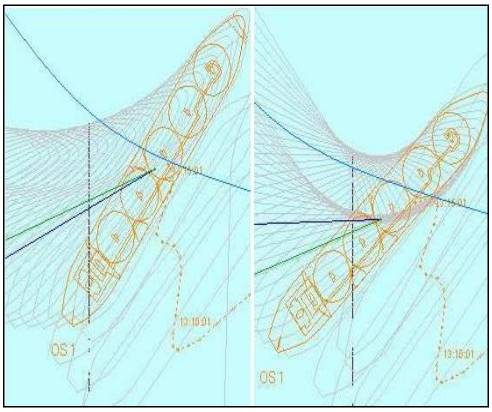


Figure 6 Increasing the main engine's revolutions in the attempt to shove off the ship

The new parameters chosen for the study have very high variations of their values (figure 7), especially the parameters chosen for hydrodynamic resistance, rolling moment (marked with a green line) and lateral force moment (marked with a blue line), reaching extreme values, from negative to positive.

It must be mentioned that in real cases, when the ship is grounded with part of the bow on the bottom and the stern is free to move and thus floating and the propeller is totally submerged (in our case the bow is grounded for about 90 – 100 metres of the ship's total length), when the main engine is used 'astern' at a high level of revolutions per minute, the stern rises and this makes the bow 'go deeper' into argillaceous soil, and this does not help in any way in our particular case.

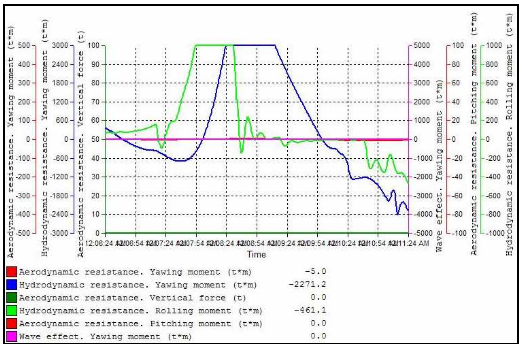


Figure 7 Variation of the new chosen parameters

The method used to refloat the ship, namely using her own means of propulsion and rudder's angles did not manage to free the ship.

3. SIMULATIONS ON CAE ANSYS12.1

In order to determine the structural response of the hull's construction elements, first a study may be developed in order to create the refloating process conditions, using the hull's model on which pressures and structural loads generated by the respective situation are applied.

The model adopted for performing this study is that of an oil tanker with the following characteristics:

- Maximum length 333 m
- Length between perpendiculars 320 m
- Maximum width 60 m
- Displacement 364018.9 metric tons
- Draught when fully loaded 22,522 m
- Height of the free board when fully loaded 4,65 m

Figure 8 VLCC Ship, chosen for developing the geometrical model (www.aukevisser.nl)

The execution of the hull had as a basis the ship's body plan (www.simman2008.dk), modelling first the plating and bridge parts after which a rigidity element were added.

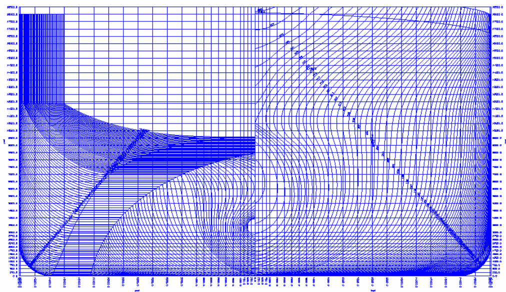


Figure 9 The basic body plan for the mathematical model

In order to simplify the modelling process, limited first of all by the available calculus power, from the 231 couplers, 40 theoretical couplers were used, and rigidity elements of the structure were also simplified. The model was executed with the CAD SolidWorks 2010 software.

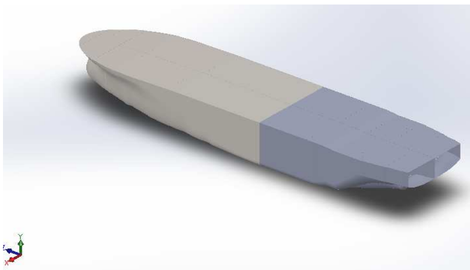


Figure 10 The three dimensional model

It was considered that the plating parts have a width between 10 and 13 mm, made of steel type AISI 1080, normalized at 900°C, and cooled under air.

In order to establish the loads to be applied on the model, this is subjected first to a study CFD performed through CAD / CAE Ansys 12.1 – CFX.

In order to get as high an accuracy as possible, the model on a 1:1 scale was used, applying a refinement of the digitized structure from the limit layer area (Van 1998). The model used for this study is the one developed for the structural analysis.

The simulation parameters were established, considering that during the refloating procedures the ship has not the maximum draught, setting therefore a 7 m draught both at the bow and stern. Also, for the functioning conditions of the propelling installation when going astern, a maximum speed of 5 knots was considered, corresponding to the speed of 2.6 m/s.

The calculus field is limited to 50 m from the stern area and four times the maximum length, on the Oz axis, respectively four times the maximum width and height of the model on Ox and Oy axes.

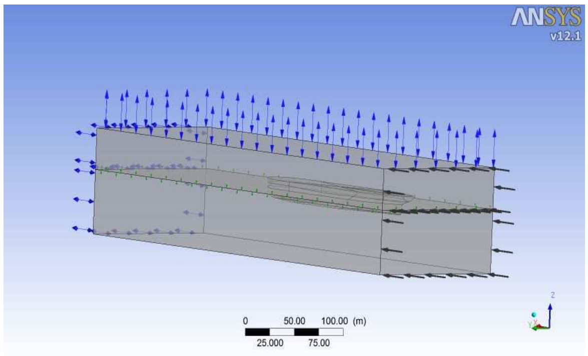


Figure 11 Determination of the calculus domain

Following the digitization process, 393208 knots and 1478147 elements resulted for the whole digitization structure. Further on I have analysed variations of the values of forces as well as pressures and speed at the flow around the immerse hull.

Following the study of the results, the conclusion is that in order to analyse the structure it should be kept in view a towing force of 219.86 kN, corresponding to an approximate load of 12% of the nominal power of the main engine when making headway. This resultant force when going astern in the case of the free body ship, calm water case, is the force which needs to be added to the friction force resulted from the contact between the bottom bow – ground (light grounding), in order to determine the total towing force at the maximum speed of 5 knots, corresponding to an intermediary transitory stage of the displacement operations when refloating the ship (in the initial phase t=0 of the refloating operations the ship's speed is zero).

It is well known the fact that in order to re-establish the manoeuvring capacity of the ship if she goes aground, there are two possible alternatives:

1. Refloating the ship by using the propulsion system onboard;
2. Refloating the ship by using tug boats – push boats.

In the first situation, when trying to refloat the ship by her own means, the purpose of such a structural analysis is to determine the ship's hull response to arising pressures and to establish the convenient maximum regarding the hull's pressures and the pushing/towing force of the main engine. The purpose is for this determination to be expressed also as a percentage of the available power of the main engine.

In order to reach such a goal, a structural static analysis is considered to be appropriate, considering the fact that registered peaks do not vary according to the simulation time. 3D-FEM (Ansys) model is developed for the supplementary pressures' analysis in the VLCC tanker's structure, in the initial grounding phase (displacement from the grounding location, zero speed of the ship) with the ship's own propulsion, in the case without water hole (light grounding), for the case of loading when damaged (7 m draught).

Due to structural complexity and the available calculus power, the model presented in figure 13 was simplified, on one hand establishing a symmetry plan, defined by the ship's longitudinal plan, and on the other hand, the model includes the main platting for the ship's hull, with a very simplified idealization of the frame elements, without pressures from her own weight and hydrostatic push, considering as a reference the case of equilibrium ship – fluid – ground in the light grounding stage. Practically the extreme case is considered when in the initial phase of displacement, the friction force is very high (modelled through constraint), including 7 values in the study for the longitudinal towing force (generated by the ship's own propulsion system) starting with 100% of the pushing force and continuing with 95%, 90%, 85%, 80%, 60% and 40% of the pushing force.

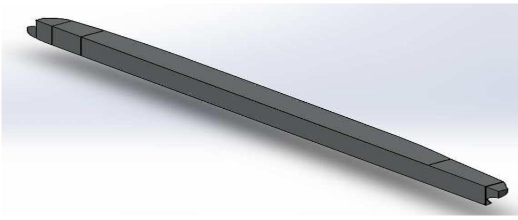


Figure 12 The geometrical model after applying the symmetry plan

The geometrical model was introduced in the sequence software CAD / CAE Ansys Workbench 12.1, resulting in a digitized structure with a maximum length of the element of 0.7 m, minimum length of 1.0002×10^{-5} m, successive elements' size having a transition rate of 0.272. The number of knots of the digitized structure is 228328, and the number of elements is 678594.

In the next stage, the defining manner of constraints and loading models was established. In figure 13 their definition manner is presented.

As previously mentioned, the model will be considered as constrained in the contact area with the ground, on the surface of 32 m^2 (figure 13), and afterwards it will be applied at the pushing bearing level with a force uniformly distributed on its surface on Oz direction.

For all considered situations, the maximum values for the Equivalent Tensions Von Misses are established in the limited interval by the couplers 4-5.

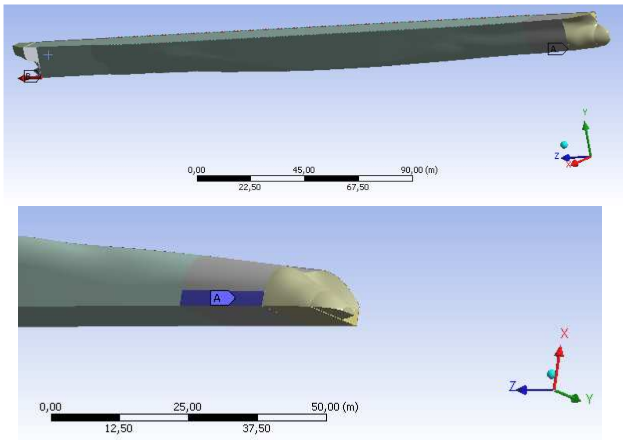
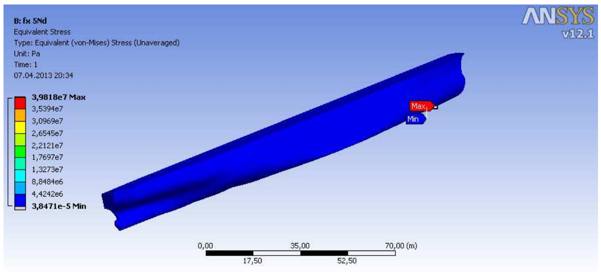


Figure 13 Edge conditions and FEM structural model loadings

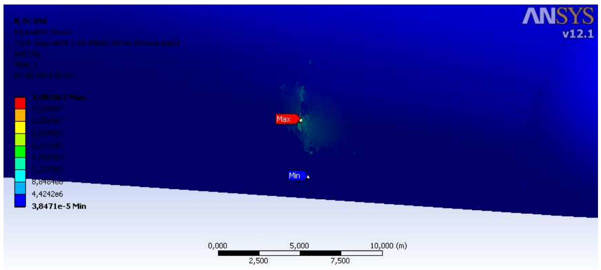
A – constraint in the contact area with the bottom

B – towing force

In figure 14, local variations of the Von Misses tensions are presented for the analyzed model.



a) von Misses tensions for the maximum loading case



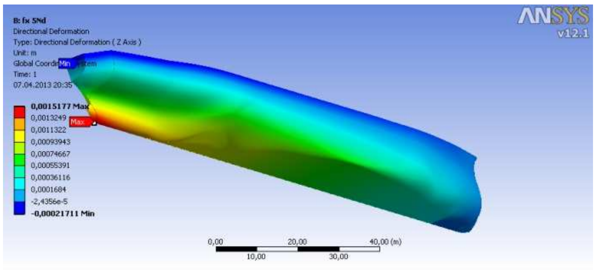
b) detail of the maximum and minimum values for Von Misses tensions in the joining area of the platting for the maximum loading case

Figure 14 Variation of equivalent tensions von Misses for the seven loading cases

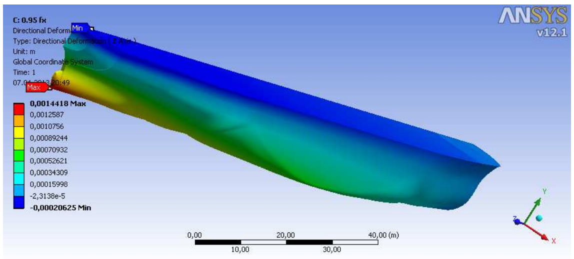
It is noticed the fact that in the joining area of plates right near the constraint area, tension enhancers are registered generating peaks of the determined values.

Analyzing the maximum values of tensions equivalent and comparing them with the established value for the limit flow of the material used (55×10^7 N/m^2), it is noticed the fact that for neither of the analyzed cases does it exist the danger of reaching some characteristic values for the plastic deformation field.

Further on, the study of specific deformations proceeds on the development direction of the towing force in order to determine the areas in which they reach maximum values.



a) movement on Oz axis for maximum towing force



b) movement on Oz axis for 95% of the maximum towing force

Figure 15 Movements on Oz axis for the seven simulated situations

As expected, the maximum deformation area along the Oz axis is the joining area between rigidity elements at the stern and the pushing bearing. This leads to an interest for facts related to elastic deformations developed on the pushing bearing level.

Considering the registered values for the observed dimensions, it can be noticed that the structure's answer during a possible refloating manoeuvre is favourable, without the existence in normal conditions of the suspicion of touching the rupture limits for the plates' material and rigidity elements.

At the same level, relatively high values of movements being observed, which in the maximum towing forces area reach peaks of over 10 mm, in order to overcharge the joints of the structural elements, the avoidance of applying forces with amplitudes higher than 175.88 kN may be considered.

For this value of the towing force, considering the existent main engine onboard the ship taken as a model (MAN B&W 7S80ME-C) and considering the next estimated values of capacity of the component elements of the propulsion system: propulsion capacity: 50%; axes line capacity: 98%; mechanic capacity of the main engine: 80%, it results in the next values for established powers on the level of every element in the propulsion system:

- towing power: 1356.03 kW;
- propeller power: 2643.34 kW;
- indicated power of the main engine: 2996.68 kW.

Knowing the effective power of the main engine, 31570 kW [www.man.com] respectively, and reporting to the determined power for the studied situation, it results in a charging of the main engine of 9.5% of its nominal power.

4. CONCLUSIONS

My research emphasizes the fact that the actions taken for refloating a grounded ship are time-critical and environmental conditions may improve or worsen with time, but the condition of a grounded ship steadily deteriorates. The manoeuvre presented by our research is represented by the attempt of refloating the ship by using the means present onboard (ship's own means of propulsions and rudder's angles). The longer the ship remains in a grounded position, the higher are the possibilities for a ship to suffer severe damages and a pollution event to occur.

The method used to refloat the ship, namely using her own means of propulsion and rudder's angles did not manage to free the ship. Future research will take into consideration to perform ballast/de-ballast operations, move the cargo from the forward tanks to another ship and eventually to ask for external help. All these further actions imply extra costs that must be supported by the owner and they are almost every time the last options taken into consideration.

Another interesting conclusion is that in the case of pressures higher than 80% of the maximum determined force for going astern, pressures on the structural elements' joints are high enough to necessitate further consideration from masters. It is clear that there are situations in which masters have to use the maximum capacity of the propulsion system in order to refloat the ship, but it is recommended in such situations to thoroughly inspect the structural elements' joints situated in the pushing bearing area afterwards, which is actually the most elicited area.

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