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HYDROSTATIC TEST ON TANKS DURING THE SECTION STAGE OF A SHIP: THE CASE STUDY OF THE PSV 5000

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ABSTRACT

In the modern shipbuilding, the construction and assembling of parts and block units are made far from the water, in specialized workshops. In this way all the work is performed in a more efficient way, with the possibility of more accurate prediction of the delivery time and cost control. To move an activity in an earlier stage of production, before the launching of the vessel, represents a competitive advantage for the shipyard, namely the reduction of the risk of bottleneck and of any possible delays on the final delivery day with the saving of millions because of penalties. The objective of the present work is to study the feasibility to perform the hydrostatic test on tanks during the section stage of the construction. It is taken into analysis the case of the PSV 5000, the challenges and the advantages that it brings.

Keywords: Hydrostatic test, section stage.

1. INTRODUCTION

The hydrostatic test is framed from the international rules (IACS S.14; Lloyd's Register; etc.) as a structural test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design.

The test is required on all types of tanks present on board in consideration of the different types of structure and location. Only after this test the class society assigns the usability of the tank and it is accepted by the client.

So the hydrostatic test (h.t.) could appear a simply secondary activity in the whole complexity of the shipbuilding construction but it is a *condicio sine qua non* for the final delivery. In the actual organization of the ship production process at DAMEN Galati, the hydrostatic test is performed after the launcing of the ship.

The possibility to perform the hydrostatic test (h.t.) at the section stage of the fabrication process of the vessel could have a positive impact on the entire production chain.

The main goal is to find the point of construction stage where technically it is possible to carry out the test and to verify that this constitutes an advantage for the shipyard. Technical, economical and quality evaluations must be done.

2. HYDROSTATIC TESTING

A hydrostatic test is a way in which tanks can be tested to ensure the safety, reliability, and leak tightness of pressure systems.

A test is required for a new system under pressure before the use or an existing pressure system after repair or alteration. In a shipbuilding process, a hydrostatic test is performed before sea trials. The tests must always be performed under controlled conditions, following an approved test plan, and written down in a test record. A single approved test plan may be used for several similar tests, but a separate test record is required for each.

The test involves filling the tank with a liquid, usually water and measuring the permanent deformation of the tank. The presence of water inside the tank creates a hydrostatic head on the sides of the tank, consequently the structure must be stiff enough to sustain this pressure.

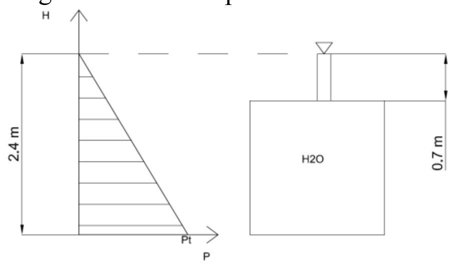

Fig.1. Hydrostatic test scheme

The value of the height of the water column prescribed by the rules can be equal to the value of the overflow or increased [1]. For increasing the water column, a temporary pipe is added on the tank top to reach the missing height. The maximum value is established based on the type of tank and its position.

Where practical limitations prevail and hydrostatic testing is not feasible (for example when it is difficult, in practice, to apply the required head at the top of the tank), hydro-pneumatic testing may be carried out instead.

This test is a combination of hydrostatic and air testing. The tank is partially filled with liquid and an additional air pressure is applied. When a hydro-pneumatic testing is performed, the conditions should simulate, as far as practicable, the actual loading of the tank. The value of the additional air pressure is at the discretion of the class society.

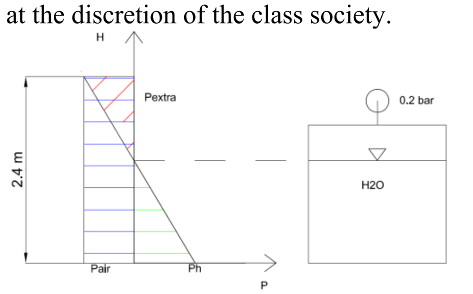

Fig.2. Hydro-pneumatic test scheme

In this case, part of the pressure is given by the hydrostatic load (green line) of the liquid (that does not reach the prescribed height) and the remaining part by the air (blue line) with a pressure of 0.2 bar.

The tank is subjected to an extra-pressure, given by the superposition of the two loads. The two tests are equivalent but the hydro-pneumatic one involves risks because an excessive air pressure (compressive effect) can cause damage to the structure of the tank. The hydro-pneumatic test must be done with caution.

The actual structural test plan in use for the tanks which aimed to contain oil of the PSV 5000 ship in Damen Shipyard Galati (D.S.G.), contains instructions to carry out the structural test with oil and compressed air instead of filling the tanks only with water. In this case a hydro-pneumatic test is used, with 10% of Fuel Oil plus air at a pressure of 24 kN/m^2.

3. FEASIBILITY ANALYSIS OF THE H.T. IN EARLIER STAGE

The main objective of this analysis is to find the point of construction stage where technically it is possible to carry out the h. t. without disturbing or minimizing the interferences with other production aspects.

The whole analysis is structured in three main steps. The **Building Strategy Analysis** highlights eligible stage points where to perform the h. t.. Subsequently these points are subjected to the **Planning Analysis** for obtaining the calendar date when to startand end the test. When the points of the building process are obtained and are structurally suitable, they are inserted in the **Load Analysis** and eventually rejected if the total load on each support below the ship exceeds the limit of 50 tons. Moreover, for each tank, the singular peculiarities that influence the whole process of testing must be analyzed.

This process is not divided in separate non-communicating blocks, but it is a continuous iterative process, where elements of different analysis could influence each other.

3.1. Building Strategy Analysis

Initially it is necessary to identify the tanks that are subjected to the test. From the

Tank Pressure Test And Structural Test Plan it is read that a total amount of 24 tanks must be structurally tested. Using the *Tank Capacity Plan,* it is possible to collect all the information necessary regarding the position and the volume of the tank. A superposition of the drawings is possible because they are made for the same section views.

Knowing the exact positions of the tanks and the frames of the ship, it is possible to identify the fabrication blocks which each tank belongs to. For this purpose the *Block Fabrication Plan* is used that contains all the boundaries block for the whole vessel. Each block contains a part of the unit under fabrication. For reasons of efficiency, these are assembled in specific workshops / assembling areas and after their completion, are transported in the dry dock (PSV 500#2 case) or in another area where the blocks are erected and joined together.

From the *Building Strategy*, it is possible to know at which stage each block is added to the main structure. N. b. the stage does not identify a temporal moment but an order of activities, two or more activities which are not in opposition could be performed at the same time.

Only six tanks are entire when the blocks are completed, but the test cannot be performed at this moment on these units because the only load that acts on the structure is the hydrostatic pressure. Weights of the upper structures and pieces of equipment are not present and the hull integrity misses. Thus the conditions of testing are far from the final state of construction and service, so the structural response cannot be the same and the test does not have any effectiveness.

The tests are run when an advanced completion of the structure is reached, so that the structure may have integrity and all the loads weigh upper the tanks and have a correct distribution on the supports.

In this case two moments are present when the tanks are tested, phases that divide tanks in the fore part and tanks in the aft part. This was made taking into consideration the fact that the development of the assembling starts from the centre going to left as far as the stern and from the centre to right as far as the bow. The tests of the tanks in the aft part of the vessel are postponed till the stage where all the stern structure is completed, this happens at stage 41.

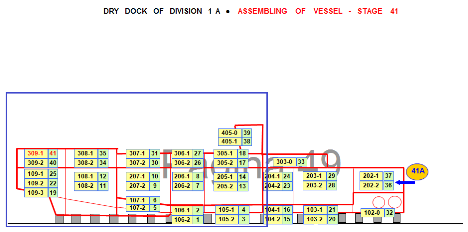

Fig.3. Building at stage 41

The structure of the aft part is complete and the main loads such as engines, generators, pumps are installed on board, so the proposal is to perform the tests at this moment. Because with stage 41 (with the assembling of the block 309-1) the stern is completed, at the same time it is possible to progress with the assembling of the fore part like it is planned in the building strategy meanwhile the tests are performed without stopping the operations of erection.

The frame of reference is number 65, so all the tanks located on the left of frame 65 are tested, locking the longitudinal section, and they are below the main deck with the upper structure completed. The remaining tanks to be tested are located in the fore part of the vessel, on the right of frame 65, locking the longitudinal section.

These are structurally completed and with the critical pieces of equipment installed (generators, anchoring and manoeuvring systems, etc.) at stage 50. At the main structure the superstructure must be added, built according to a separate sequence.

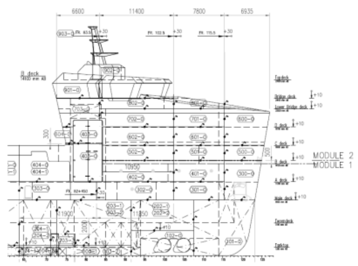

Fig.4. Building at stage 50

3.2. Planning Analysis

It is analyzed the interaction of the previous proposals of h.t. in the earlier stage on the actual planning of the PSV 5000#2. The two stages to be identified in the planning are 41 and 50.

Stage 41 corresponds to that moment of the building process where all the stern structure is completed. The level of completion desired is reached on August 4th, 2015, with the assembling of block 309-1 to blocks 308-1 and 109-1.

But two more dates emerge from the Planning Analysis due to the degree of completion of the whole structure: August 24th 2015 and September 18th 2015.

On August 26th the assembling of block 204-1 to blocks 205-1 and 104-1 is completed. On September 18th the assembling of block 405-0 to the main structure is completed.

But from the weight estimation according to the actual planning for vessel PSV 5000 #2, August 4th is not eligible because sections 204-2 and 204-1 are not completely assembled to the main structure since the end of the operations is estimated for August 24th . So even if the weight of the sections puts pressure on the structure, they contain part of tanks 35, 37, 38.

Considering the days when the operations are supponsed to start and end, a detailed weight estimation is created in relation to the above dates. The reference weight is the one at stage 41 of the building strategy. But the actual planning presents some differences in the order of the execution from the building strategy, because the planning is related to the production capacities of the shipyard and the other projects carried out at the same time.
The total weight is different for the three dates:

Table 1. Weights at stage 41

	Total weight at 41 stage	weight 04 Aug	weight 24 Aug	weight 18 Sep
Kg	23936323	1671450	2162233	2342228
	%from the T. W.	69,83	90,33	97,85

How is it possible to note already that on August 24th it is reached more than 90% of the total weight. Most of the missing weight is due to the fraction of the piping not completed in the sections. And it is possible to notice that major part of it is located in the structure on the right side of frame 65 so not vertically located on the tested tanks.

The hull at stage 50 is complete and the tanks inside it could be tested after October 5th 2015, at which point the assembly of section 300-0 ends. For this day the superstructure that will be added to the main body must also be considered.

3.3. Load Analysis

It is necessary to do the calculations for the evaluation of the loads applied on the blocks when the ship is in the dry dock. These calculations are done in relation to the main topic of the study. So they are performed taking into account that the load will not be referred to the complete ship before the launching. At the earlier stage (41 and 50), the ship is partially completed, plus the mass of water load contained in the tanks.

In D.S.G. software CVSL_64 is used that allows to find the reaction force on the blocks according to their number, disposition and spacing along the vessel.

The first step to be done in order to run this software is to give it some input data that contains all the information on the weight of the ship. So, it is necessary to create a detailed weight estimation.

The weight estimation is compiled on an excel sheet, this file extension can be read by CVSL_64. Because the objective is to be focused on the section stage, two excel sheets are created, each for two different moments of the building strategy. They refer to the stage 41 and the stage 50.

Moreover, in the weight estimation are inserted the characteristics (mass, CoG, start, end) of the 24 tanks that must be tested.

Based on the weight estimation, it is possible to simulate different scenarios of loading, activating one or more tanks with the coefficient. Prior to each stage point, it is verified that the starting condition of a correct load distribution is met without any concentrated loads on the supports. Only afterwards, the tanks are activated in different configurations aiming at finding the best one.

CVSL_64 is the software in use in D.S.G. for different purposes: for the stationing of the hull during assembling, for the moving of the vessel inside the yard or for the calculations necessary before launching. It is based on the Beam Theory, where the load is distributed transversely and longitudinally on all the supports below the ship.

In this type of calculations the load is a Static Load [4], they are related to a specific load condition and they do not have any variation while the load pressure is being exerted.

The software takes into consideration the frame spacing of the ship and it distributes the loads along the transverse supports. The loads, centre of gravity and extension are known, they do not act on a single frame but are supported by multiple frames. Nevertheless, according to the nature of these loads, there are Local Loads [4]: they are loads applied to a limited portion of the ship.

The Finite Element Theory could give results closely related to the main peculiarities of the local structure that is sustained by the supports. The choice to use a software program based on the beam theory, instead of one based on FEM, is justified by:

1) CVSL_64 is the software daily used in DAMEN shipyard.

2) The necessity to have results in short time. This characteristic is fundamental because in the case of last moment changes during the production process, it is necessary to have immediate results.

3) The maximum limit of 50 tons allowed on each support is far below the safety limit above which a permanent deformation occurs.

From the analysis of the actual planning of vessel PSV 5000 #2, two suitable dates are found for the test of the tanks located in the aft: August 24th and September 18th. And one date for the remaining tanks in the fore part: October 6th .

The analysis, according to the level of completion reached, has revealed that August 24th is not appropriate to support an extra load, derived from a not ideal distribution of the weight that brings to concentrate loads on two supports. They are located respectively in x= -2,400m , y= -10,700m and x= -2,400m , y= 10,700m. These two supports are loaded with 55,586 tons against the 50 tons allowed. It is understood that these 5 tons of extra load are not critical and temporarily they can be accepted, but of course it is not possible to weigh the structure with extra weight of several tons of water mass.

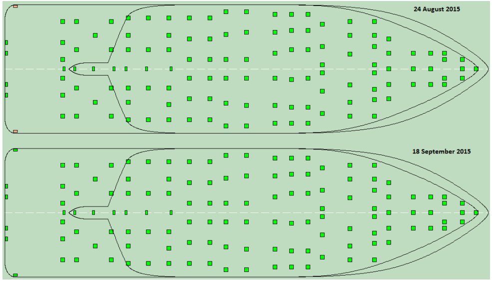

Fig.5. Loading comparison

With the load estimation of 18 September 18th, the two supports have a load of 47,364 tons against 55,586 tons of August 24th. For this reason, the date of August 24th is excluded. Then all the analyses of the supports loaded by the added mass of water of the tanks of the aft part are performed using the weight estimation corresponding to the one of September 18th.

For performing the h. t. four more supports are placed below the hull with respect to the original arrangement, as shown in Fig. 6. The reason is that all the simulations have shown that the most solicited supports are located in the sterns on the side. But the increase of the number of supports in this area presents one main difficulty: the area under the arch stern must be free for the pod propeller and its insertion. These supports are four pillars of dimension 760mm x 400mm with a capacity of 50 tons.

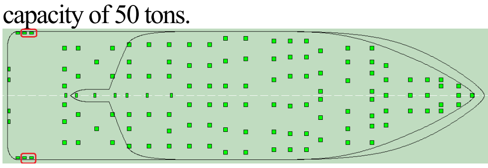

Fig.6. New supports arrangement

The tanks cannot be tested all together for two reasons:

1) Some tanks are adjacent, so they have in common one side. They must be free to be inspected and to deform (in the case it happens). Thus it is not possible to have on the same structure two opposite forces that tend to deform on the opposite side, so they cancel each other.

2) The total weight that results is excessive.
For these reasons the total amount of tanks in the aft part is divided in 8 sub-groups with a maximum of 4 tanks. For planning requirement, these groups could be switched in the sequence.

4. SCHEDULING ANALYSIS

In continuation with the previous analysis, the hydrostatic test program is inserted in the actual planning. In this analysis, the previous starting dates proposed, September 18th and October 6th are taken into consideration along with the duration of each test for one tank. In this way the definitive dates for each single test are found. For this goal the proposal of modifying the actual planning is put forward in consideration of the fact that some activities could overlap each other.

The limited number of devices that are actually present in the D.S.G., influences the maximum number of tanks that could be tested at the same time. If in the previous paragraph is obtained the maximum number of tanks filled at the same time from a structural point of view (no overload), now that number of tanks cannot be reached for limitations in the equipment. So each group is divided. The Shipyard is equipped with two pumps for loading operations and two submersibles for unloading, so it is possible only to load two tanks at a time. By connecting all the activities and their duration, it is possible to obtain the calendar dates.

It is simulated that for the tanks located in the aft part, the operations starting day is **18/09/2015** and the end day **30/09/2015.** For the tank positioned in the fore part, the operations starting day is **06/10/2015** and the end day **14/10/2015.**

This solution allows to end all the activities related to the testing (filling, cleaning, restoring of the tank, etc.) one month before the launching of the vessel as currently planned.

5. CONCLUSIONS

The whole study has revealed that it is possible to perform the h. t. in the earlier stage, before the launching.

This solution has the following advantages:

- In case a test fails, there is time to make the necessary modifications to the structure and it is easier to intervene on the ship located in the dry dock than in the case of a floating ship.
- Easier planning in accordance with other activities, no overlapping!
- Better efficiency in the single activities, organizing the testing groups in sequence.
- Economic savings.
- Possibilities of improvements with the acquisition of new equipment.
- This strategy is suitable also for other types of vessel, especially the ones without systems on boards such as Multi Purpose Pontoon.

Particular attention must be paid to:

- Avoid concentrated loads on supports.
- Select the exact moment of the execution according to the building strategy.
- The necessity of external devices, the ship is not self sufficient.

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