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MOUNTING AND TESTING TECHNOLOGY FOR A STEERING GEAR SYSTEM WITH HYDRAULIC CYLINDERS

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ABSTRACT

The steering gear system is part of the group of vital installations for a ship. Its role is to ensure course stability and, at the same time, to facilitate the changes of navigation direction. In this context, the technology for assembling the system is well-defined through rules, procedures, and work instructions. A steering system that is correctly assembled according to the instructions and execution drawings will lead to proper operation and, at the same time, the successful completion of applicable steering system tests. The applicable tests for steering systems are depending to the type and purpose of the vessel. However, SOLAS defines a series of general high-level tests that must be performed, and during these tests, the quality of the installation is to be demonstrated. The present work will develop both the subject of the steering gear installation, which directly influences the results of the tests.

Keywords: steering gear, rudder, mounting technology.

1. INTRODUCTION

The steering gear system has the role of ensuring the ship's maneovrability and also course stability. Course stability is the property of the ship to maintain the imposed navigation direction. In this sense, the steering gear system is used only to keep the ship on the required trajectory. In other words, the scope of the steering system is to correct the instability of the course due to the wind and the currents acting on the vessel during the voyage. In the second case, the steering gear is used to change the navigation direction or to avoid an obstacle.

The testing methods of the installation have the role of ensuring that the ship with the steering gear system meets the functional requirements and the registry requirements.

From the point of view of the nature of the forces transmitted to the ship, the steering installations can be active or passive. For the active steering installations - the necessary steering forces are obtained by special thrusters that involve energy consumption. For the passive installations the necessary steering forces are obtained by the interaction between the rudder and the water current, the energy consuming only for the positioning of the rudder in the current.

2. RUDDER CONSTRUCTION

The rudder studied and presented in this paper is the suspended type, fixed to the shaft by a conical grip and a nut, and it is fixed to the hull of the ship through the frame and the bearings in the frame.

In figure 1 is presented the rudder and the main construction elements, the rudder shaft, but also how the rudder is attached to the ship's hull.

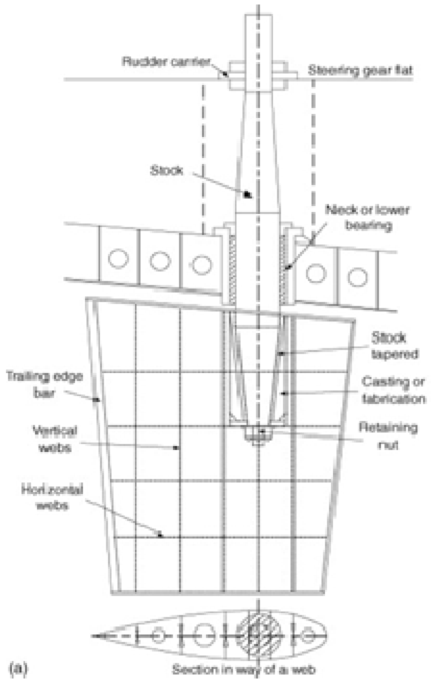

Fig. 1. Rudder construction

The construction of the rudder starts from the main dimensions which it's can be seen in figure 2. Strength calculations was not performed for the components of the rudder. Therefore, the materials thickness was considered not relevant for this study.

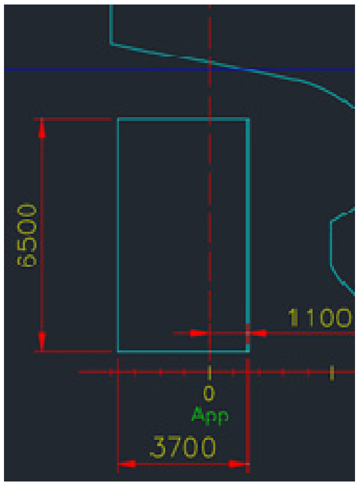

Fig. 2. Rudder dimensions

The first step in the construction of the rudder is cutting the materials. The materials are cut and marked by the plasma cutting machine in accordance with the manufacturing preparation document that is entered in the data base of the cutting machine.

After the parts are cut, the rudder sheets are sent to shaping to create the shape of the rudder profile. In order to achieve the necessary curvature, the boards are constantly checked with wooden templates that take the shape of the rudder profile.

Knowing that it is a rudder with considerable dimensions, in order to facilitate its construction, an assembly bed is made that takes the shape of the rudder, then its assembly begins.

3. MOUNTING OF THE RUDDER

Mounting the rudder includes two main stages:

– Mounting the shaft in the rudder;
– Mounting the rudder-shaft assembly to the ship;

3.1. Mounting of the rudder stock into the rudder blade

The first step in mounting the shaft in the rudder blade is to check the contact surfaces between the conical part of the shaft and the inner surface of the bush located in the rudder blade.

Checking the surfaces by the contact spots method is a procedure for evaluating the level of contact between two components. In the specific case of the rudder wedge bushing and the rudder shaft.

Checking the contact between the surface of the bushing and the shaft by the method of contact points is done taking into account the following steps:

- Surface cleaning: The shaft and bushing must be cleaned before testing. This ensures that there are no particles of dust or dirt that could influence the results.
- Application of contact paint: A contact paint or pigment is applied to the outer surface of the shaft or the inner surface of the bushing. This paint should be thick enough to leave a visible stain, but thin enough not to distort the actual dimensions.
- Matching attempt: Insert the spindle evenly.
- Removal and inspection: After the shaft has been matched, both sides are removed and inspected. Areas where paint or pigment has transferred from the shaft to the bushing (or vice versa) indicate the points of contact between the two parts.
- Interpretation of the results: If the contact points are uniform and well distributed, this indicates a good fit between the shaft and the bushing. If the stains are concentrated in certain areas, this indicates that there is a problem-either the shaft is deformed or the bushing is not manufactured correctly.

The rudder stock is to be pulled into the bushing by help of a hydraulic nut. With the equipment mentioned, the rudder stock mounting operation proceeds as follows steps

1. Check that the mating surfaces of the bushing and the rudder stock do not have any burns or scratches and that they are clean. Grease with oil these surfaces with the same oil as is used for the pumps. Lubricate the o-rings with oil and mount them in each slot, then open the ventilation hole (the first one from the top) so that the oil can come out after inserting the rudder shaft into the bushing. The rudder shaft is guided vertically into the bushing until it reaches a position, caused by its own weight.
2. Screw the hydraulic nut together with the washer into the rudder shaft. Check that the pistons of the hydraulic nut are retracted as far as possible.
3. After all the air is forced to out of the hose, it's connected on hydraulic nut one of the pumps with the quick connector. Oil is pumped into the nut until the pressure indicated by the manometer is max. 50 bar. This is the starting position for the drive-up length of the rudder stock into the bushing.
4. The second pump is connected to the first oil inlet and oil is pumped until the oil comes out through the second inlet, then the hose is connected and oil is pumped under pressure into the bushing simultaneously and into the hydraulic nut. While oil is being pumped into the bushing and into the hydraulic nut, the value indicated by the measuring equipment is followed, and after it is determined that the advance of the shaft in the bushing has been achieved, the oil pumping is finished. The recorded values of the pressures from the hydraulic nut and from the expansion of the bushing are noted and compared with the values indicated by the manufacturer.

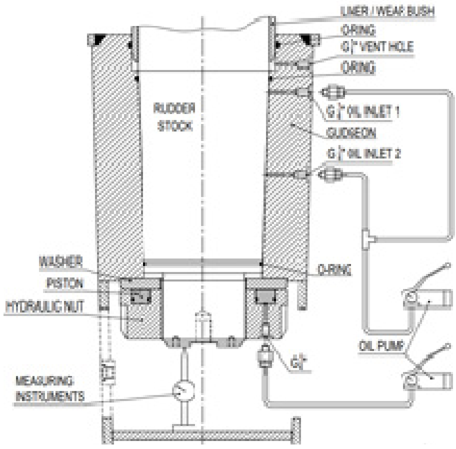

Fig. 3. Pull-up of the rudder stock in udder blade

5. The pressure in the hydraulic nut is maintained for half an hour (or as indicated by the manufacturer) and release the pressure from the rudder bushing. After this time, release the pressure from the hydraulic nut, thread the screws from the hydraulic nut where the pump was connected, then tighten the nut and secure according to the instructions in the drawing.
6. The securing plate is fitted to the rudder shaft with bolts, then the fixing bolts are secured by welding.
7. The securing strips are mounted in opposite positions in the recess in the hydraulic nut, then they are welded to the nut fixing plate according to the detail in the drawing.

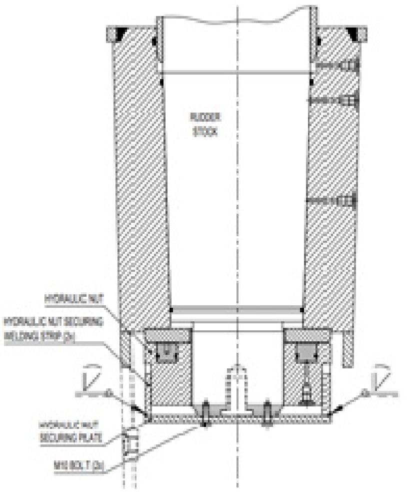

Fig. 4. Securing detail for the hydraulic nut

3.2 Mounting the ruder and shaft assembly to the ship

This step can only be performed if the bushing alignment in the rudder trunk and the main engine shaft line alignment have been performed. The bushing to be inserted into the tube in the rudder trunk, is inserted into a container with liquid nitrogen to contract. After they reach the ambient temperature, the bushing is removed from the container and the necessary measurements are taken inside. In the ship's structure, on the hull, lifting eyes are provided for handling and mounting the rudder. The rudder is also provided with handling and lifting eyes. Thus, using the lifting equipment of the shipyard, the rudder is transported under the ship's hull in the stern area, where it is caught in the hoists and raised in the vertical position. The rudder-shaft assembly is raised, the shaft enters through the bushing and at the top it is fixed in order to mount the rudder machine and the movement transmission mechanism.

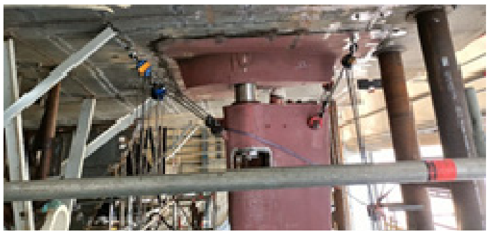

Fig. 5. Mounting of the assembly to the ship

4. MOUNTING OF THE STEERING GEAR SYSTEM

To avoid hydraulic losses on the piping system, it is preferable for the hydraulic power unit to be as close as possible to the rudder machine. Thus, having the rudder machine and the hydraulic power unit in the same compartment, there will be minimal hydraulic losses.

According to Bureau Veritas Classification Society, NR 467, Part C, Ch 1, Sec 11-2.4.3 - The steering gear system must be independent from the other systems of the ship. In this sense, the hydraulic power unit used only serves the steering gear system.

The first step in mounting the equipment in position is mounting the foundations. These are mounted according to the outfitting drawings, are welded to the ship's structure, then are painted and after painting, the equipment can be mounted. In the case of the hydraulic power unit, this is attached to the foundation with screws. The holes on the equipment are measured, then are marked on the foundation and the holes are performed.

For assembling the rudder machine, the first step is mounting of the tiller arm, then the cylinders are mounted in relation to the tiller. The rudder is positioned at 0 degrees, i.e. in the diametrical plane and fixed, the tiller arm is mounted in the rudder shaft, then the cylinders are also mounted. The tiller arm is designed in such a way that it has the necessary lenght to achieve the maximum rudder bending angle

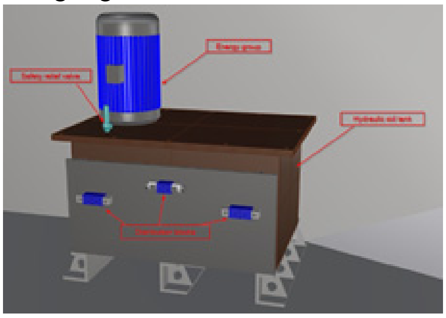

Fig. 6. Mounting of the HPU – 3D model

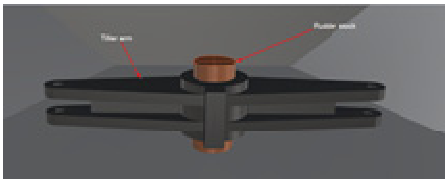

Fig. 7. Mounting of the tiller arm

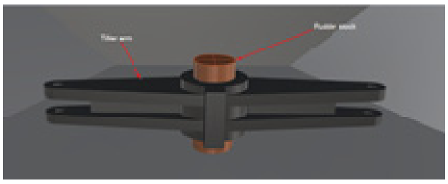

Fig. 8. Mounting of the hydraulic cylinders

The piping system is assembled according to the schematic diagram and also, according to the isometric drawings provided by the designer.

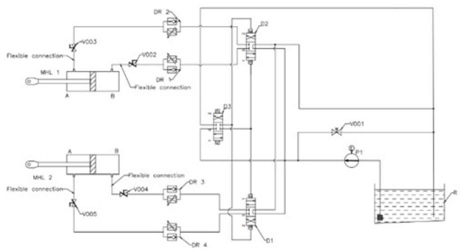

Fig. 1. Hydraulic diagram

The first step is to make the connections on the manifold on the hydraulic power unit, then the pipes to the hydraulic cylinders is mounted and the final connections are made. After the piping installation, it's performed the strength testing of the system according to the requirements of the classification society. The strength test of the system, are performed at the pressure of 1.5 x Working pressure of system. After completing the pressure test, the system is flushed according to NAS 1638 / ISO 4406 which is specified in the functional diagram of the installation. The ISO Cleanliness Code, ISO 4406, 1987 is perhaps the most widely used international standard for representing the particulate contamination level of industrial fluid systems. According to ISO 4406, cleanliness is classified by a two-number code, e.g. 16/13, based on the number of particles larger than 5 µm and 15 µm, respectively, in a known volume of fluid.

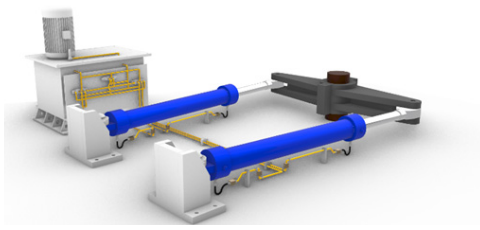

Fig. 10. Arrangement of the system

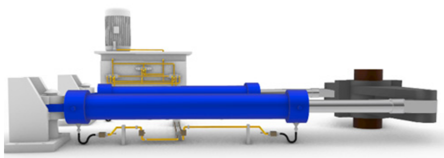

Fig. 11. Side view of the system

5. TESTING METHODOLOGY OF THE STEERING GEAR SYSTEM

Maneuverability represents the property of the ship to maintain its course on an imposed direction and the property of the ship to move under the action of external forces, propulsive forces and governing forces along a certain trajectory. These two characteristics determine the functionality of the installation in two navigation regimes:

- Driving regime - in this case, the governing system is used to maintain the default trajectory by correcting road stability.
- Maneuver mode - in this case, the steering system is used to change the navigation direction or to avoid an obstacle.

The ship's maneuverability can be described by the following specific qualities:

- the ability to initiate a maneuver as quickly as possible to avoid an obstacle (maneuver of rotation);
- the ability to maintain a high speed in the turning maneuver;
- the ability to get out of the turning movement;
- the ability to stop the ship in a short time and at a distance as small as possible;
- the ability to maintain the navigation direction, in the absence of external disturbances (wind, waves, sea currents).

The main standard maneuvers recommended by the ITTC and IMO organizations are:

- turning the ship,
- exiting the gyration,
- the zig-zag test,
- the spiral maneuvers (direct and reverse), the stop tests (inertia and crash-stop).

5.1 Turning of the ship

The turning of the ship is a maneuver used to determine the qualities of maneuverability. The turning diameter gives the size of the circle that the ship describes when the rudder is banded to one side or the other (after the movement stabilizes).

The ship's maneuverability is better when the turning diameter is minimal.

In the first phase, the maneuver of turning the rudder into a board, with 35 degrees, is performed. Due to the inertia of the ship, the drift angle is zero.

Second phase begins with the appearance of the first non-zero values of the drift angle and the tangent component to the trajectory of the velocity vector.

In the third phase, the turning radius is constant over time, and the ship's trajectory becomes an arc of a circle. In order to determine the physical parameters of the ship's turning, it is necessary that the turning circle measures at least 540 degrees.

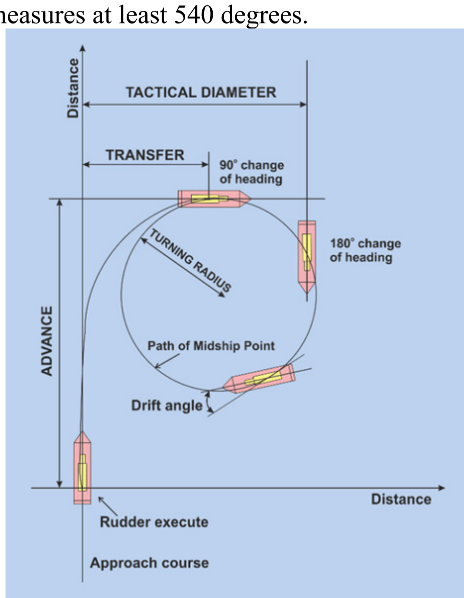

Fig. 12. The turning manoeuver

5.2 The exiting gyration

This maneuver is used to determine the directional stability of a ships. In the initial phase, the ship advances on a straight road at a constant speed. The rudder turning maneuver is performed on board, with a preset angle of 20 degrees. The ship enters a roll trajectory, and when the ship's horizontal roll angular velocity stabilizes, the rudder band angle cancels out and the roll angular velocity decreases in time. The gyration exit maneuver is a very simple test, which however requires calm weather conditions and a correct interpretation of the measurement results which can be influenced by the action of the wind or the direction of rotation of the propeller, for ships with only one.

5.3 The zig-zag test

The zig-zag maneuver is used to determine the ship's ability to rapidly change the head angle. The zig-zag maneuver (also known as the Kempf maneuver) is used for the more in-depth study of the ship's initial response to rudder bending. The results of the zig-zag tests are dependent on the ship's speed. By decreasing speed of the ship, the advance and the overtaking angle decrease.

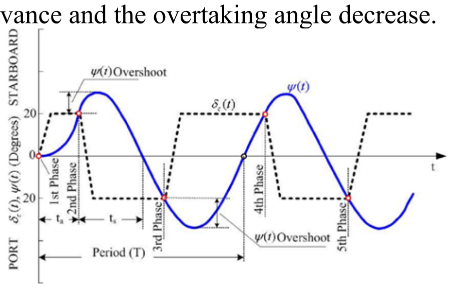

Fig. 13. The zig-zag test

5.4 Spiral maneuvers

Spiral tests are used to determine the road stability performance of the ship. Two types of spiral maneuvers are distinguished: direct spiral and the indirect spiral.

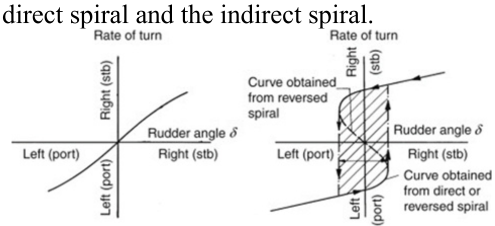

Fig. 14. The spiral test

5.5 The crash stop test

The stopping maneuvers highlight the ship's qualities related to the need to stop immediately in dangerous situations.

Types of crash-stop tests:

- The sudden stop maneuver (crash-stop) is carried out at the maximum speed of march forward and consists in passing the propulsion machine with all the power to march back;
- the low-speed stopping maneuver, recommended by the current practice of ship exploitation, consists in passing the full power of the engine reverse propulsion, in conditions where the ship moves at low speed;
- the inertia maneuver is carried out at the maximum forward speed and refers to stopping the propulsion machine and measuring the parameters the trajectory traveled until the vessel stopped.

5.6 Acceptability criteria of maneuverability tests

According to IMO MSC 76/23/Add.1 ANNEX 6, the acceptability criteria of maneuverability tests are [16]:

- Turning ability

The advance should not exceed 4.5 ship lengths (L) and the tactical diameter should not exceed 5 ship lengths in the turning circle maneuver.

- Initial turning ability

With the application of 10 rudder angle to port/starboard, the ship should not have traveled more than 2.5 ship lengths by the time the heading has changed by 10 from the original heading.

– Yaw-checking and course-keeping abilities

1. The value of the first overshoot angle in the 10/10 zig-zag test should not exceed:

- 10 if L/V is less than 10 s;
- 20 if L/F is 30 or more;
- (5 + 1/2(L/V)) degrees if L/V is 10 s or more, but less than 30 s,

where L and V are expressed in m and m/s, respectively.

2. The value of the second overshoot angle in the 10/10 zig-zag test should not exceed:

- 25, if L/V is less than 10 s;
- 40, if L/F is 30 or more;
- (17.5 + 0.75(L/V)), if L/V is 10 s or more, but less than 30 s.

3. The value of the first overshoot angle in the 20/20 zig-zag test should not exceed 25.

– Stopping ability

The track reach in the full astern stopping test should not exceed 15 ship lengths. However, this value may be modified by the Administration where ships of large displacement make this criterion impractical, but should in no case exceed 20 ship lengths.

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