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Structural and Fatigue Strength in Shipbuilding: Ensuring Integrity and Safety in Maritime Engineering

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Abstract: When navigating through water, a ship encounters a multitude of complex forces due to the influence of currents, gravity, and buoyancy. This complexity renders the calculation of both structural strength and fatigue strength particularly challenging. Consequently, the ultimate strength method and the total longitudinal strength method are commonly employed for assessing the structural strength of ships. For evaluating the fatigue strength, which involves numerous additional factors, a more systematic approach is required, typically involving fatigue strength verification and lifespan assessment. This paper explores the methodologies used for calculating the strength and fatigue strength of ship structures.

Keywords: Strength of ship structure; Fatigue Strength; Computing technology.

1. Introduction

With the development of society, the exploration of the ocean is nearly endless, so the scale of all kinds of ship companies is expanding, and the corresponding communication repair companies are also increasing, the task of ship repair is more and more. In this case, as a result of the various problems, if the use of improper repair, but will further reduce the ship's ability to resist risk, or even counterproductive. Therefore, the structural strength and fatigue strength of the ship structure are studied and calculated, and then combined with the ship repair engineering to improve the repair quality and ensure the safety of the ship structure.

The gravity of the hull is uneven along the length of the ship, and the shape of the bow and stern of the ship is sharp and thin, the middle part is large, the volume of the water drained from each part is different, and the buoyancy generated is different, the gravity and buoyancy of the ship along the captain's direction are not evenly distributed in the captain's direction, so the total longitudinal bending force is produced. There are two kinds of longitudinal bending of ship hull: one is that the ship hull is arched in the middle section, and the bow and stern part is sagging, which is called "mid-arch Bending" ; the other is that the hull hull is sagging, and the bow and stern part is upward called "mid-sag bending" . The former state results in tension on Deck Longitudinal members and compression on bottom longitudinal members, while the latter state results in the reverse. When the hull is in longitudinal bending, the members under compression often buckling due to excessive compression, which greatly reduces the ability of the hull to resist longitudinal bending. It is an important content to analyze the longitudinal strength of a ship hull to analyze whether the structure is buckled or not and the residual capability of resisting external force after buckling. When the ship is sailing in the waves, the total longitudinal bending force is bigger, when the wave crest is in the ship, the mid-arch bending will be strengthened, and when the wave trough is in the ship, the mid-sag bending will be strengthened. If the wave length is equal to the captain, the situation will be more

intense. This is the most dangerous for a sailing ship. The appearance of this most dangerous condition must be taken into account in the study of the overall longitudinal strength of a ship. The members of the hull including the outer plate, Longitudinal continuous bone, continuous upper deck, longitudinal bulkhead, bottom structure, broadside longitudinal bone, the middle longer base and superstructure, especially the long bridge building, the Middle Deck compartment in the area of 0.5 l, the length is more than 15% of the ship's length and 6 times of its own height.

2. The Structural Strength of the Ship

The structural mechanics of a ship, in essence, is the situation where the hull is subjected to force or even deformations while sailing in water, and these will be calculated during the design of the hull, the structural strength of the ship hull is calculated by the given loads transmitted from outside when the structure of the ship has been determined. Therefore, the calculation of the structural strength of the ship largely depends on the design concept of the ship, basic mechanics, mechanics of materials and other mechanical theory to calculate. However, in the actual calculation process, in order to be easy to calculate, it is necessary to simplify the structure of the ship and to control the external loading force on the ship, thus, the strength calculation of stress and deformation of ship hull in the course of water flow is calculated by using the theory of ship.

3. The Analysis of the Structural Strength of the Ship

The ship is consistent with the calculation of the structural strength, the calculation of ship’s strength at the time of design and construction, while in the repair of a ship, these structures remain unchanged, even if they are legislative and energy methods, the displacement method and the Matrix method are unchanged. So in this and the process can take a structure to calculate.

Mechanics solution is one of the more basic and common methods in ship structure. The principle is to remove the factors that can not be controlled and form a statically stable structure. In this way, the desired equation can be obtained, after removing the uncertain factors, the deformation equation is basically the same as that of the original structure. Taking n as the unknown force, there will appear "force regular equation"

Using displacement method to solve the structural strength of the ship, which is relatively comprehensive, mainly using the setting of the node rotation angle, the solution is carried out once by using a balance condition of the moment of a section of the node. Its basic principle can be understood as finding the number of rotatable nodes from the nodes of the structure, and then restricting the number of nodes in the corner, then according to the specific equation listed bar end bending moment, and finally establish the equations of each node, so as to get the right answer.

The calculation of the total longitudinal strength generally speaking, there are standards for the calculation of the total strength of a ship. The first is to place the ship in the waves of the simulated environment that has been prepared for the test, and the tentative ship is travelling in the waves, and the direction of travel is consistent with the direction of the current, so that the propagation and the current are at a relative rest. Second, the ship is also placed in a simulated environment, where the standard waveform is a two dimensional tangos wave, so that the captain is the wavelength, you just have to do the relevant calculations. The third is to take the limit value for calculation, that is, the peak and trough of the two kinds of limit state for calculation. In this way, the wave bending moment and wave shear force can be calculated.

Calculation of wave bending moment MW (+)and vertical wave bending moment Mw (-) in ship transverse section:

$$Mw(+)=+190MCL^2BCb\times10\text{-}3 \quad KN\cdot m \tag{1}$$

$$Mw(-)=-100\ MCL^2B(Cb+0.7)\times10\text{-}3 \quad KN\cdot m \tag{2}$$

In this equation, M is the distribution coefficient of bending moment and L is the length of ship, B is the width of the boat, and CB is a coefficient of the square, but it has to be within 0.60.

C=0.0412L+4 L<90m

C=10.75-(300-L/100)3/2 20m<L<30m

C=10.75 300m<L<350m

C=10.75-(300-L/100)3/2 350m<L< 500m

The calculation of the total longitudinal strength is based on the calculation of the forces acting on various parts of the ship body mechanism.

$$Fw(+)=+30F1CLB(Cb+0.7)\times10\text{-}2 \quad KN \tag{3}$$

$$Fw(+)=-30F1CLB(Cb+0.7)\times10\text{-}2 \quad KN \tag{4}$$

As the ship body is composed of many parts, in the calculation, the forces acting on the ship body structure in actual operation are reasonably analyzed, and then determine the structural strength of the hull. In the case of the transverse skeleton, if it is assumed that only the force of water is transmitted, the force to bear the water must be the bottom plate under the hull, which in turn is transversely consolidated and transmitted to the various structures of the hull.

For example, the longitudinal skeleton is used, it is still assumed that the force of the water collected by the Hull is transmitted to the outer bottom plate, which in turn is transmitted to the Longitudinal Skeleton, and then to the frame. Therefore, the calculation of the total longitudinal strength usually takes into account the transfer of forces between the components. In the transfer of forces, the hull is transversely deformed or bent.

4. Fatigue Strength of Ship

The fatigue strength of ship means that the structure of ship is damaged in the period because of the influence of force. In addition, whether the hull is loaded or not, due to the impact of water, or the impact of wind and waves, the hull will be subjected to additional damage, such damage perennial lightning strike, the fatigue strength of the ship will be seriously affected, and then the quality of the ship will be affected. In fact, the fatigue degree of the hull is closely related to the material, bearing strength and service life of the hull. Therefore, in the calculation of the fatigue strength of ships, there has not been a clear algorithm so far, but the fatigue strength of ships can be estimated to a certain extent, so that the fatigue strength of ships can be roughly calculated, to extend the life of the hull structure.

Simulation software computing method there are many mainstream simulation software at present, but generally the software itself has a lot of huge database, which can meet the needs of various experiments. Multisim simulation software as an example, Multisim simulation software is mainly used in a variety of simulation on the circuit, including circuit design and testing and analysis, and other aspects of the experiment, can visually show the operation of the circuit, bring clear knowledge transfer to students. Multisim simulation software contains a lot of technology, involved in many areas of circuit knowledge and principle, circuit automatic control, circuit simulation and crisis interface circuit is one of the links.

Multisim simulation software has a rich storage of components library, not only to meet in different conditions, under different circumstances of the experiment, but also to ensure the fidelity of experimental data, to ensure the unity of experimental data and actual data. In addition, Multisim simulation software has a lot of components and PF component model, so students can be based on the actual experimental situation, automatic programming, very practical.

Fracture mechanics method generally speaking, the study of fatigue strength of ships is to a great extent based on the problem of fatigue fracture of ships, only in this way can the fatigue value of ships be accurately estimated.

The fracture mechanics method of ship is a very effective measure. The fracture mechanics method, which is based on Paris's law of crack propagation, assumes the existence of cracks in the hull (in fact, any material is microscopic in the presence of cracks) , mainly in simulations, then, under the action of the external force, the process of crack propagation is studied, and the effect of crack

initiation on the fatigue strength of ship hull is judged.

S-N curve method is to accumulate S-N curves through numerous experiments, so that S-N curves in various ship structures can reflect a damage of fatigue degree to a great extent, the life of the remaining hull in operation and the strength of the fatigue analysis in the structure of the ship can also be calculated.

Therefore, the S-N curve is also called the stress amplitude curve, which is the direct-viewing curve of the fatigue life of the reaction ship. Therefore, in the experiment, with s as the stress amplitude of alternating stress, then n naturally represents the stress cycle number of the ship under the action of this force, that is, the fatigue life we want. In fact, there is still some uncertainty in the experiment, so it is possible that the final budget will be slightly different. For example, whether the model can really replace the actual ship in the test, the fatigue error of the ship and the form distribution in the fatigue secretary's statistics will affect the S-N value.

In the relatively mature curvilinear coordinates at this stage, are the following two model curves:

$$N=AS^{-m} \qquad N>Nq \tag{5}$$

$$N=CS^{-V} \qquad N<Nq \tag{6}$$

The random load and fatigue cumulative model the random load and fatigue cumulative model is also a commonly used method for predicting the fatigue strength of ships. As the hull structure is always in the state of fatigue load, the alternating stress will continue to increase, gradually accumulating damage to the fatigue strength of the ship. Generally speaking, the ship's random load is made up of waves, impact, transmitter or propeller, the slight touch of the bottom of the ship, etc. . The cumulative fatigue damage is also based on the S-N curve, which obeys many density functions. In general, random load and fatigue cumulative model designed to calculate the fatigue strength is also very much, not to enumerate.

There are many factors affecting the wave bending moment, such as: When the Square Coefficient CB increases from 0.6 to 0.8, the wave bending moment increases by 40% . The CB of conventional tanker is about 0.8, while that of FPSO is more than 0.9.As a result of the different spectrum, the energy distribution with the frequency is different. The JONSWAP spectrum, for example, focuses most of its energy in a narrow band, and it is easy to understand why its response is different from other spectra. Four wave directions. It is generally considered that the bending moment of vertical waves is the largest when facing waves. Generally speaking, the wave bending moment mainly depends on the shape of waterline, the shape of Cross section, the moment of inertia radius and the wave parameters.

5. Conclusion

Through various sailing experiences, the structural strength and fatigue strength of the ship hull is an important point that can not be bypassed in the design and operation of the ship, which is related to the quality and service life of the ship. Therefore, we must pay attention to this question in the design, through to the structural strength computation and the fatigue strength estimate, designs the good performance ship.

The loading of ship hull structure is very complex, and some members produce several kinds of stresses at the same time. For example, in addition to the total longitudinal bending stress, the outer plate, as a part of the hull plate, produces local bending stress under the action of water pressure, and as an effective belt plate of bone material, deforms together with bone material and produces local bending stress. So when checking the strength of the member, the member itself should bear the most unfavorable load combination, analyze the stress composition of the member, and judge whether it meets the requirements according to some specified strength standards. Generally speaking, the "Longitudinal strength check" is to check the overall longitudinal bending stress and shear stress of the hull section, and the buckling strength check caused by the overall longitudinal bending stress.

In the overall longitudinal strength checking of a ship, the actual shear force and bending moment of the checked section are usually compared with the maximum shear force and bending moment of the section, provided that the former is not greater than the latter, it is considered that the ship in the loading state can meet the Operation Safety Requirements, which is the basic idea to check the longitudinal strength of the ship.

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