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Research on Structural Strength of 7800 PCTC under Flexible Design

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Abstract. In this paper, we use the finite element software MSC·PATRAN and MSC·NASTRAN to establish the FEM model. Then we analyze the racking condition strength under the conditions of inclined shipping, and discuss the stress of the hull structure, the distribution of the hot spot and the deformation of the deflection under the flexible design concept. Some general conclusions under the design concept are obtained, which will be expected to contribute to the development of the design concept of the whole ship flexible structure..

1. Introduction

Car Ro-Ro ship, dedicated to carrying vehicles. With the vigorous development of the global automobile industry, the international auto trade is rising, to achieve the "national car" national strategic objectives and solve China's automobile export shipping "bottleneck" to facilitate the Chinese car to the world, it is imperative[1].The existing structure of the car Ro-Ro ship is designed for traditional rigid design and flexible design [2][3].The traditional rigid design means that when the hull is subjected to external forces, the horizontal inertial forces borne by the deck are transmitted to the side strong ribs through the deck beams, resulting in deformation of the ribs under lateral forces [4].

The concept of flexible structural design was first proposed by the DNV, widely used in practice. The flexible structure is mainly through the use of flexible components, with its deformation to buffer and consume the force and energy delivered by other structures, so as to prevent the tearing of structure [5]. When the ship is subjected to an asymmetric load, it is easy to produce a large transverse moment resulting in a roll. The inertia force of the cars due to roll reacts on the deck, under the action of the shear effect, the horizontal strong frame's shape of the Car Ro-Ro ship prone to oblique deformation, that is, Racking state. For conventional ship types, the Racking phenomenon is usually resisted by the deformation of the shell and the deck of the transverse bulkhead. But because the Car Ro-Ro ship almost no horizontal bulkhead, so the Racking of the hull will be completely bear by the horizontal strong frame. This is where should be paid attention in the design of the Car Ro-Ro ship, also be considered as an important feature of the Car Ro-Ro ship. Therefore, the lateral strength of the Racking state is also the key to the strength check of the Car Ro-Ro ship.

2. Finite element calculation

Using the finite element software MSC · PATRAN and MSC · NASTRAN, referring to the DNV [6], we study the strength of the whole ship of the 7800 PCTC under the flexible design concept. Calculating the inclined shipping state, which is, racking condition. The load calculation is based on the RINA [7].

In this study, we use the 7800 PCTC with total 13 floors of the vehicle deck, of which 3,5,7,9 layers are Movable decks, and the sixth floor deck is the watertight deck and throughout the whole ship. Using a single propeller drive, double bottom structure, all decks are the vertical frame type.The principal particulars of the 7800 PCTC are summarized in Table 1.

Table 1. Vessel principal particulars

Vessel principal particulars			
Length OA, L_{OA}	199.9m	Length BP, L_{BP}	187.70m
Depth of the main deck, D	15.335m	Breadth, *B*	36.45m
Depth of the top deck, D	34.275m	Designed draft, d	9.50m
Block coefficient	0.5324	Service speed	20.2kn
Frame spacing	0.85m	Strong frame spacing	3.4m
The horizontal spacing of two rows of pillars	13.9m	The longitudinal spacing of two rows of pillars	13.6m
Double bottom height	1.825m		

2.1. Finite element model

The whole ship model of the 7800 PCTC under the flexible design concludes a total of 298614 nodes, 518528 units. Among them there are 186939 beam units and 331589 plate units. Finite element model as shown in Figure 1.

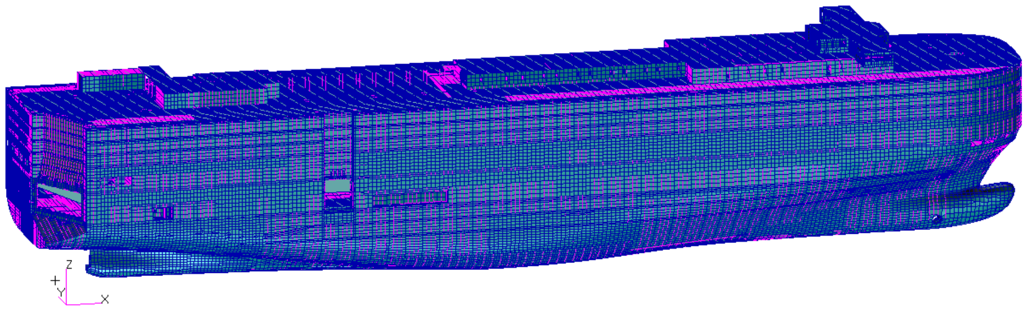

Figure 1. Finite element model

2.2. Load cases

Ranking condition is mainly check the structural strength Caused by Racking transverse deflection, under the asymmetric load effect, in the inclined shipping.

The load divided into vertical load P_V and lateral load Pt.

The two conditions are also subject to the hydrostatic pressure of 9.5m draft, the ballast of the ballast tanks and fuel tank, and the horizontal bending moment (Racking Moment), ignoring the wave dynamic pressure and the weather deck load.

In final calculation results of Racking, it is necessary to superposition the calculation result of the local load and the overall load (Racking Moment).

The Load loading diagram of Racking as shown in Figure 2, and the loading of local load in model as shown in Figure 3.

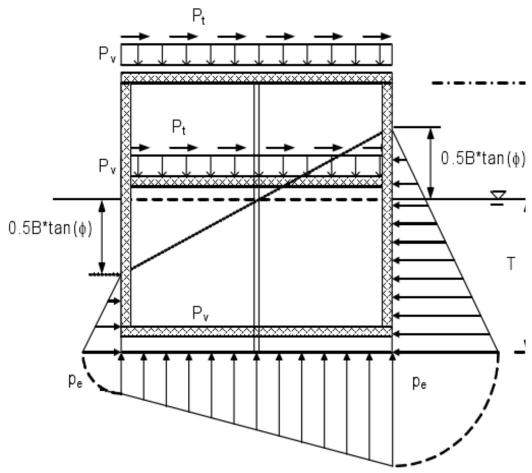

Figure 2. The load loading diagram of Racking

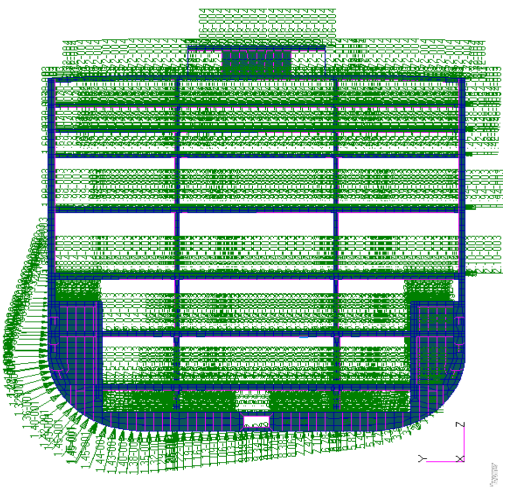

Figure 3. The loading of local load

Due to the incomplete symmetry of the whole ship structure of the 7800 PCTC, it is necessary to calculate and check the leftward Racking_1 condition and the rightward Racking_2.

2.3. Boundary condition

2.3.1. Boundary condition of Racking. According to the CN31-2[8], the guidance document of the DNV, the boundary conditions are located on the three nodes of the freeboard deck in the bow and stern, when calculating the load of the 7800 PCTC in the Racking condition. As shown in Figure 4.

Boundary conditions are assigned on boundaries as follows, the node in the bow performs u, v and w constraints, the node of port side in the stern performs w constraint, and the node of starboard in the stern performs v and w constraints.

Where u, v and w denote the translational displacements in x, y and z directions respectively.

It is found that the restrained reaction force of the whole model is very large at the constraint point and its surroundings, and also the stress of the other main structures is particularly large, as shown in Figure 5. In the traditional way of reduce the constraint, the restraint force in the six directions is minimized by applying external force to the whole ship model. But the traditional way is cumbersome and inefficient, so we choose inertia relief.

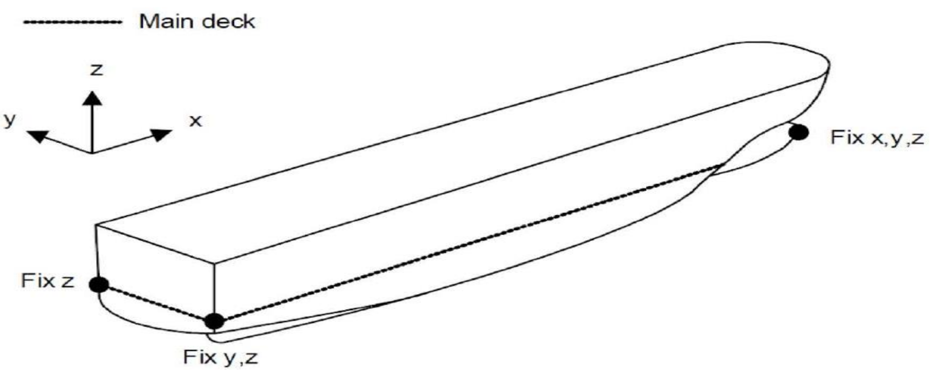

Figure 4. Boundary conditions of Racking

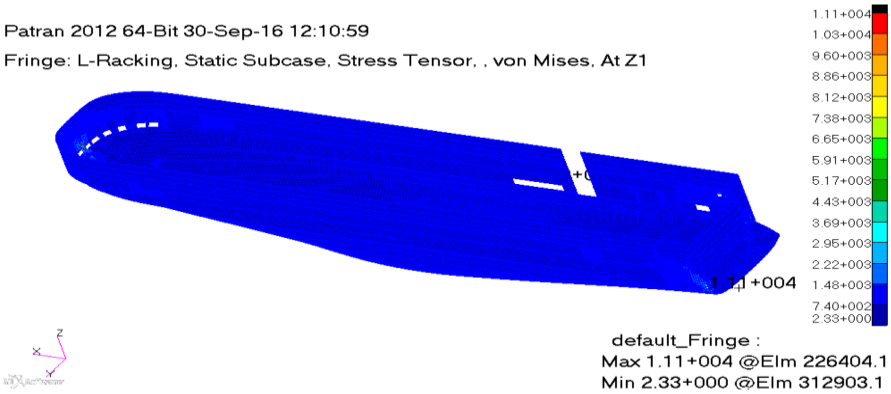

Figure 5. The stress distribution of the constraint points and surroundings in Racking

2.3.2. Inertia relief

Using inertia relief to carry out boundary constraints- applying a virtual constraint force in the structure, to ensure the balance of the structure of the force. Briefly, the inertial force of the structure is used to balance the external force. In detail, firstly, using the Finite Element Method to construct the static and dynamic equilibrium equation. Then, solving the equation to get the node's acceleration which used to maintain the balance, and then get the inertial force of each node. Adding the inertia force to the FEM node as an external force added, and then constructing a self-balancing force system.

The static and dynamic equilibrium equation constructed by FEM:

$$\{F\} + [M]\{\ddot{\delta}\} = 0 \quad (1)$$

Where,

{F} is the external load vector consist of component of all the nodes

$$(f_x \;\; f_y \;\; f_z \;\; m_x \;\; m_y \;\; m_z),$$

$\{\ddot{\delta}\}$ is the acceleration vector consist of component of all the nodes

$$(\ddot{\mu} \;\; \ddot{v} \;\; \ddot{w} \;\; \ddot{\theta}_x \;\; \ddot{\theta}_y \;\; \ddot{\theta}_z),$$

M is mass matrix：

$$M = \int_{\delta} \rho [N]^T [N] d\delta. \quad (2)$$

Inertia relief needs to select a node applying 6 degrees of freedom constraints, which is virtual support. The displacement obtained by inertial relief is the displacement of each node relative to the "virtual support" in the full Free State, so the different position of the virtual support will get the different displacement results. Referring to the available information, we select the middle node of the bottom of the ship as a virtual support.

2.4. Design load

There are the design load of 7800 PCTC under the inclined shipping: Racking moment, the uniform load considered the deck weight, the hydrostatic pressure of 9.5m draft, the ballast of the ballast tanks and fuel tank.

3. Results

In the paper, we check the equivalent stress of the main structure, in the racking condition. Calculation results as shown in Figure 6 to Figure 8.

Where, c is side plate, d is bottom girder, f is strong side frame, g is deck beam, h is fuel oil tank, j is outboard plate structure.

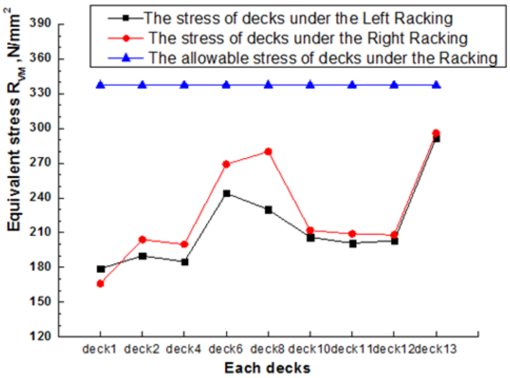

Figure 6. The stress of decks

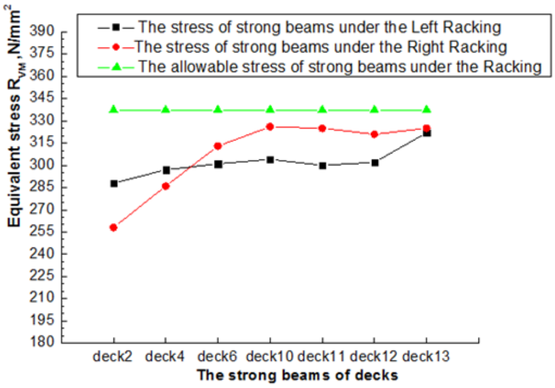

Figure 7. The stress of strong beams of decks

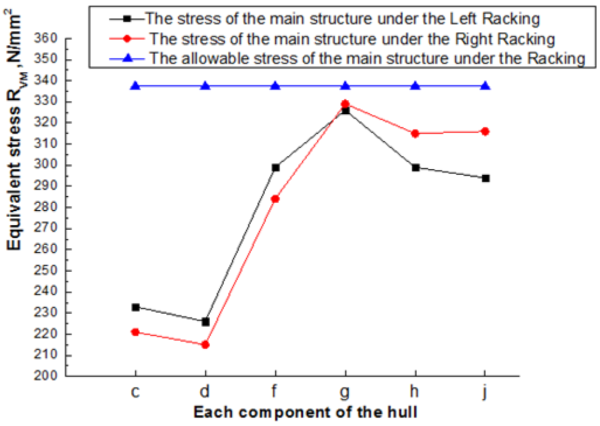

Figure 8. The stress of the main structure of the hull

4. Conclusions

Under the calculated conditions, through the analysis of the calculation results of the strength of the whole ship, the following conclusions are drawn:

- Overall, the structural strength of the 7800 PCTC meet the requirements. But there are still individual units of the main structural area, of which the strength close to the critical value. For these high stress areas, we can Improve structural strength by Increasing the local thickness or using the high strength steel.
- Under the Racking conditions, we found that the strength of the strong beams and the Internal frame of the fuel tank of the deck 10 and deck11 also close to the critical value. In the design and construction, these areas should be taken seriously.

- Above the Deck05 (freeboard deck), we Use the concept of flexible concept design. And under the Deck05 using the rigid concept. So, in the region of the upper and lower, the difference of the ribs stress is significant, attention to avoid stress concentration. In addition, the layers of the deck and the pillar connection, strong stringer and pillar connected, should be in the design and construction to be taken seriously.
- The related research in this paper is not sufficient for fatigue and buckling strength, which should be considered in future research.

5. Acknowledgements
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