Finite element analysis of building block ark

Strength Analysis and Design of Building Block Ark Based on Finite Element

Hongyan Li, Yu Wang*
School of Qingdao University of science and technology, Qingdao 266061, China.
*Corresponding author e-mail: 4570536@qq.com

Abstract. The research on the building block ark can be divided into two key issues: first, the hydrodynamic performance analysis of the building block ark, the main content is to study the hull shape and main scale of the building block ark. The second is the square of blocks. The strength analysis of the boat is mainly to study the overall structure and local strength of the building block ark. This article will explore the Lord. The content is the structural strength analysis of building block ark.

Keywords: block ark, strength analysis, finite element analysis.

1. Introduction
The building block ark is the earliest splicing catamaran built at home and abroad. A catamaran is a ship connected laterally, such as the middle deck. A long time ago, it was found in shipbuilding that the two hulls, connected horizontally, could sail more smoothly on the sea or Inland River [1]. The discovery led to the earliest use of the hull for the construction of sailboats, which can withstand higher winds and waves due to its unique hull. Compared with ordinary ships, catamarans of the same tonnage have larger deck area and larger cabin capacity, and have more stable characteristics. In addition, if the design of the catamaran is reasonable, it can also consume less energy and greatly improve the navigation speed [2]. It can be said that the emergence of catamaran is an important milestone in the history of ship development [3]. There are two sides of the hull of the catamaran. When the hull shakes due to wave impact and fluctuation, the stability of the catamaran is several times that of the ordinary monohull. Its excellent stability makes the catamaran quickly become a new favorite in the field of ship design and research [4].

2. Building block Ark design scheme
The structural strength of the building block ark is more complex than that of the single ship or even the catamaran. Therefore, the research and design of building block ark is less than that of ordinary single ship, and there are a lot of ship models and real ship data. In view of this situation, the structural strength of the building block ark is calculated. The design scheme of building block deck the ship is composed of a sharp floating body, a floating body, a connecting body, a L-shaped deck, a Z-shaped deck, a U-
shaped deck, a baffle, a guard board and a cover plate. Building block ark is a new type of ship, similar to catamaran. Length can be freely changed by the number of joints. It is very flexible and can be used as a pontoon. The structure of the ark and the external load under the design condition are very complex. By using the direct calculation method based on the finite element theory, the stress state of the whole ship can be calculated effectively and quickly on the basis of the reasonable establishment of the finite element model. Therefore, the ship strength calculation method based on the finite element theory is an improvement of the traditional beam theory. In this paper, the finite element calculation of the building block ark is carried out under the above premise. The main contents are as follows:

(1) Based on the development of catamaran, the research status of catamaran is discussed, and the structural characteristics and overall performance of catamaran are analyzed in detail. The finite element simulation software is explained, and the application of the finite element method in the strength calculation of ship structure is described.

(2) Measurement of the size and structure of each component, three-dimensional model of each component of the hull, assembly and overall design and drawing of some components and SolidWorks software.

(3) Analyze the strength finite element analysis of the first part of the component structure loaded by the building block ark under the forced state, meshing, imposed load and constraint using the finite element software. The calculation results are compared with the strength standards, which do not conform to the strength of the standard components and the continuous improvement of the structure, and finally meet the strength requirements.

(4) Finally, the overall strength of the hull under five different working conditions, namely, the middle arch, the middle concave and the wave surface, is calculated by ANSYS software. It includes five kinds of working condition analysis, external load analysis, load formula derivation and calculation, solution model simplification, whole ship model grid division and optimization, constraint and load application.

The deformation and stress of the hull structure are solved. The strength of the hull is judged by comparing with the corresponding strength standards, and the components and structures that do not meet the strength standards are improved. After calculation and improvement, the structure of the block cabinet finally meets the strength conditions under the design conditions, which provides a reference for further structural design of the block cabinet in the future. Through the verification and summary of launching test of physical model of building block ark, the feasibility of assembling hull design is verified. Refer to the initial simplified model building block cabinet and the continuously improved 3D model building ark, preliminarily determine the structure and size of each component, and SolidWorks software is used to design and draw the building block ark of the 3D model, as shown in Figure 1:

![Block Ark Outline Drawing](image)
2.1. Stress analysis of building block Ark

The finite element analysis of the total strength of the building block ark under five working conditions is carried out by using ANSYS software. Through the solution of the finite element software, the equivalent stress nephogram and the total deformation diagram are obtained. Due to the different load action under different working conditions, the calculated stress and deformation of the building block ark are different. The total deformation of the hull is relatively small, and the deformation will be magnified and displayed, mainly referring to the data of the deformation size. According to the calculated stress size and distribution, compared with the mechanical properties of PP material, we can judge whether the structural strength meets the requirements.

In the following, the total longitudinal strength of the building block ark is evaluated by solving the results of each working condition.

Working condition 1

The condition that the bow of the building block ark is impacted by waves.

A total of 2940N load weight is applied to the U-shaped deck between the floating bodies of deck 3, 4 and 5; the water resistance and wave force are applied to the upstream of the bow, with the size of 2520N, and the uniform load is applied to the upstream; the buoyancy is 4410N, and the uniform load is applied to the bottom of the hull. In order to constrain the displacement of the stern in z-direction, the bow is subjected to wave impact and water resistance to simulate the dynamic propulsion. Take the x-direction sideline of the upper surface of the stern joint floating body, constrain its X- and Z-direction displacement, take the upper surface of the stern joint floating body, and constrain the y-direction displacement.

![Fig. 2 Equivalent stress diagram of condition 1](image)

In this case, the inclination angle of the hull is small and the stress distribution of the deck is symmetrical on the starboard and starboard sides. Due to the wave impact load on the bow of the ark and the design driving conditions of the building block ark, i.e. under the condition of small waves, driving at low speed, the wave impact load is limited. The maximum stress of the deck is about 2MPa, and the stress of the impacted part of the bow is slightly higher than that of the middle section. The total deformation is small. Due to the small load imposed according to the design form conditions, the maximum deformation of the hull deck is 6.2mm, and the deformation of other positions is small, which can be ignored.

Working condition 2

The condition that the building ark is impacted by the wave side.

In this case, the ship's direction of travel is perpendicular to the direction of wave propulsion. Therefore, the water resistance is applied to the upstream of the bow, which is 1210N; the wave force is applied to the side wave impact surface, which is 2760N; the U-shaped deck between 3, 4 and 5 floating bodies is applied with a total load of 2940N; the buoyancy is 4410N, which is applied to the bottom of the hull with a uniform load. The X and Y-direction displacement of the outer edge line of the upper
surface of the floating body on the uninfluenced side is taken to constrain the z-axis displacement of the stern on the uninfluenced side, and the bow is subjected to wave impact and water resistance to simulate the dynamic propulsion.

In this case, the inclination angle of the hull is larger than that of case 1. The design driving condition of the building block ark is that the impact load of the wave is limited under the condition of small wave and low speed. The maximum stress of U-shaped deck is about 39 MPa, and the stress of ship side in wave impact area is increased.

Deformation: first of all, the transverse deformation of the floating body is larger than that of the first working condition. The maximum displacement occurs at the first floating body connecting deck on the impacted side, and the total deformation of the hull is about 244mm. The deformation in other locations is small and can be ignored.

Working condition 3
The moment of arching wave in the design of building block ark.
Under no-load condition, the middle part is arched upward, and both ends of bow and stern are sagging. The buoyancy of the middle part of the building block ark is greater than that of the gravity, and the buoyancy of the bow and stern is less than that of the gravity. The buoyancy of 550N is applied to the bottom of the 1 and 6 hull sections; the buoyancy of 1655N is applied to the bottom of the 2 and 5 hull sections; the buoyancy of 2205N is applied to the bottom of the 3 and 4 hull sections; the U-shaped deck between the 3, 4 and 5 floating bodies is applied with a total load of 2940N. The load is distributed symmetrically in the middle section of the hull, so the z-axis displacement of the middle section of the hull is constrained, and the x-axis sidelines at both ends of the bow and stern restrict the Y-axis and z-axis displacement.

Fig. 3 Equivalent stress diagram of condition 2
Theoretically, when the wave length is 1.05-1.1 times of the length of the ark, the wave bending moment of the building block ark is the largest. In the actual calculation, the wave length is always equal to the length of the ark. The driving conditions of the design of the building block ark, i.e. driving at a low speed under a small wave condition, are often taken. Under this condition, the middle part of the hull is subjected to a large vertical upward buoyancy and a vertical downward load weight, and the deformation of the ark is small. The maximum stress is about 9Mpa.

Working condition 4

Under the condition of the bending moment of the vertical wave in the design of the building block ark.

In this working condition, under no-load condition, both ends of the bow and stern are arched upward and the middle part is sagging. The buoyancy of the fore and aft parts of the building block ark is greater than that of the gravity, and the buoyancy of the middle part is less than that of the gravity. The buoyancy of 2205N is applied to the bottom of 1,6 two hull sections; 1655N is applied to the bottom of 2,5 two hull sections; 550n is applied to the bottom of 3,4 two hull sections; a total of 2940N is applied to the U-shaped deck between 3,4,5 floating bodies. The x-axis displacement of the middle section of the hull is constrained, and the x-axis sidelines at both ends of the bow and stern restrict the Y-axis and z-axis displacement.
The wave trough of the ark in the middle vertical state is located in the midship cross section of the building block ark. The bow and stern are subject to the greater vertical upward buoyancy, and the middle part of the hull is subject to the vertical downward load gravity, which causes the hull to deform along the direction of the hull. As the deck is not a whole, but assembled by several pieces, there is no large bending moment, and the maximum stress is about 1.5MPa.

Working condition 5
The combination of bending moment and torque of the wave in the middle arch of the building block ark.

Under this condition, the ship is sailing at an angle of 45 °, and the wave front is subjected to water resistance and wave force in the Z and X directions. The buoyancy load is not uniform, and the wave peak position in the middle of the hull is arched upward with a large buoyancy, and the buoyancy of the bow and stern is small and sagging. 2205N buoyancy is applied to the bottom of the left hull 2, 3 and the right hull 4, 5; 1655N buoyancy is applied to the bottom of the left hull 1, 4 and the right hull 3, 6; 550N buoyancy is applied to the bottom of the left hull 5, 6 and the right hull 1, 2; a total of 2940n load weight is applied to the U-shaped deck between the 3, 4 and 5 floating bodies. The z-axis displacement of the middle section of the hull is constrained, and the X-and Y-direction displacement is constrained by the side line of the right bow section of the left stern section.

Under this condition, the hull is subjected to both bending moment and torque. The stress distribution changes greatly along the boat width direction. The stress in the middle of the U-shaped deck is larger, and gradually decreases to both sides. The maximum stress value is about 7.2MPa.

3. Summary
The finite element analysis of the strength of the building block ark under different working conditions is as follows:

(1) Analyze the external load of the hull, determine the load conditions of the hull under different working conditions, and calculate the load;

(2) Analysis of working conditions: the working conditions are divided into five working conditions: the bow and stern are impacted by waves, the side is impacted by waves, the middle arch, the middle sag, the combination of wave bending moment and torque, and the transverse bending moment.

(3) The optimized building block ark is meshed as a whole, and the grid is adjusted and optimized to get a better quality grid.

(4) Analyze the strength of the ark under five working conditions. The maximum stress is 39 MPa, which is lower than the strength of PP material (45MPa), so the strength of building block ark meets the strength requirements.
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