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Optimize Longitudinal Frame of FRP Fishing Boat based on Genetic Algorithm

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Abstract

This thesis focused on the research of a 36.6 meters FRP fishing boat based on the theory of finite element analysis, under the allowable of the structural strength and rigidity of the fishing vessel, taking the weight of the whole ship as the objective function, the framing FRP fishing boat was optimized in order to make full use of the mechanical properties of FRP and achieving the lightest, which provides a scientific theoretical basis for the performance evaluation and design of FRP fishing vessels. This article can be obtained that the thickness of the hull shell, main deck and upper deck is reduced, which not only meets the allowable conditions for the strength of the whole ship structure, but also has a significant effect on the optimization of the light weight of the whole ship. The reduction of the thickness of the hat-shaped aggregate on the upper deck and superstructure has no obvious effect on the weight reduction of the whole ship and reduces the mechanical properties of the whole ship structure.

Keywords

GA, FEM, FRP fishing boat, hull structure.

1. Introduction

In recent years, with the rapid development of the FRP fishing boat industry, the concept and method of structural optimization design have also been continuously innovated and developed with the maturity of technology. In the 20th century, after the optimization design method began to be applied in the hull structure design, experts at home and abroad published a large number of papers on the optimization design of the local side plate structure of the ship, such as the plate structure of a large container ship hull section Optimization, optimization of deck openings, and optimization of ship's bow section structural strength. The results of this kind of local optimization are difficult to apply to the whole ship, mainly because the parametric modeling is relatively simple and has large errors. This has also led designers to rely on the classification society's specifications and mature design experience when designing the entire ship structure. Therefore, it is necessary to find a whole ship optimization design method suitable for different types of ships.

In general, the main purpose of structural design optimization of a whole ship is to change the ship's structural form, aggregate size, and overall layout, taking into consideration the strength and stiffness, safety, and complexity of the construction process, to achieve weight reduction of the whole ship. Focus on the purpose, so as to maximize the economic benefits of FRP fishing boat industry and fishery.

2. Structural Optimization Design Method of FRP Fishing Boat

2.1. Classification of Optimization Methods

The method of ship structure optimization can be divided into two types: normative method and direct method. The standard method is to select appropriate variables according to the type and structural characteristics of the ship and set reasonable constraints and objective functions according to the relevant codes. The direct method is to constrain the calculation results of the finite element of the whole ship and repeatedly adjust the main size of the structure to achieve Optimal design of ship structures. Therefore, it is necessary to choose a suitable optimization algorithm. The optimization method selected in this paper is the direct method.

2.2. Optimize of the Process

The most important task of optimal design is to construct a reasonable mathematical model. Determine the goal to be achieved by the optimization design, that is, the objective function, and use the programming language to build the engineering problem into a mathematical model. Select the appropriate design variables, give the design variable constraints, and finally programmatically optimize the optimization problem [1]. For the purpose of optimizing the weight reduction of FRP fishing boats in this paper, the objective function is the total weight of FRP fishing boats, the expression is linear, and the constraints on design variables are non-linear [2].

The selection of an appropriate optimization algorithm for the optimization design is related to the effectiveness of the optimization results and even the success or failure. The selection of optimization algorithms directly affects the number of design variables and constraints for structural optimization. Too many constraints will affect the feasibility of the optimization process, making it impossible to solve.

2.3. Definition Design Variables

After the preliminary design of the FRP fishing boat is completed, the main dimensions of the fishing boat, the main molding lines and the overall arrangement of the main components (mainly including the building style, the number of deck levels, the distribution of the various positions of the cabin, and the placement of equipment) have been determined They can be used as a known quantity. Therefore, the optimization of FRP fishing boat structure is mainly to optimize the properties of FRP material, the structure form and the size of structural parts, etc., and to ensure that the hull meets the mechanical properties to minimize the quality of the whole ship. The optimization problem of FRP fishing boat is transformed into a mathematical model problem, which usually includes three elements: design variables, constraints, and objective functions[3].

Due to the special nature of the material, the internal structure of the FRP fishing boat is very complicated, which leads to the diversity of the optimization design variables. However, considering the actual requirements of the construction technology of the FRP fishing boat and the feasibility of the optimization algorithm, it is assumed that the material used for the FRP fishing boat is certain. of. This article studies the lightweight of FRP fishing boats. From this aspect, the design variables should mainly select the geometric parameters of the main component, that is, hat-shaped aggregate. In this paper, the thickness of the hull plate, the thickness of the deck, the thickness of the bulkhead, and the thickness of the hat-shaped bones are selected as design variables, which are denoted as($X=x_1, x_2, ..., x_n$) [4], where is the design variable, which can be used as an n-dimensional space, and is simply denoted asR^n.

2.4. Define Constraints

Constraints are expressed in various forms, including explicit and implicit forms. The relationship between the maximum equivalent stress, the maximum shear stress of the longitudinal-frame FRP fishing boat and the size of the main components of the longitudinal-frame FRP fishing boat is an implicit constraint. The constraints established in this paper are mainly the geometric size constraints of the longitudinal-frame FRP fishing boat. And explicit constraints for stress condition constraints [5].

According to the construction guide of FRP fishing boat, and taking into account the structural rationality, construction technology, and stress conditions of the 36.6 m mobile FRP fishing boat, the overall structure of the FRP fishing boat is constrained. The geometric size constraints can be expressed as

$$x_{i,min} - x_i \le 0, (i=1, 2, ..., n); \quad (1)$$

$$x_i - x_{i,max} \le 0, (i=1, 2, ..., n). \quad (2)$$

Where $x_{i,min}$-the minimum value that meets the conditions;

$x_{i,max}$-The highest value that meets the conditions;

n -The number of geometric constraints.

With reference to the “Glass Fiber Reinforced Plastic Fishing Boat Construction Code 2008”, summarize the constraints that the main components of the longitudinal frame type glass fiber reinforced plastic fishing boat meet, including the ratio of the height and thickness of the web of the hat-shaped aggregate, the thickness of the hull slab, the thickness of the veneer structure deck, Low longitudinal frame structure hat-shaped section modulus, side frame hat shape section modulus, deck aggregate section modulus, watertight bulkhead, superstructure and deck room, hatch and other deck openings.

2.5. Define Constraints

The glass fiber reinforced plastic fishing boat has a complicated structure due to its material characteristics. The glass fiber reinforced plastic fishing boat designed in this article is a veneer sandwich structure. According to the design specifications, when designing a glass fiber reinforced plastic fishing boat, it is necessary to ensure The stresses and maximum deformations of the shaped aggregates, hull shells, main decks, and superstructures under wave loading are lower than the limits specified in the design code, and they can ensure that FRP fishing boats have sufficient strength to bear the load and equipment weight.

(1) Constraints on maximum equivalent stress of FRP fishing boat under wave load:

$$\sigma_{max} \le [\sigma]$$

(2) Constraints on the maximum shear stress of FRP fishing boat under wave load:

$$\tau_{max} \le [\tau]$$

(3) Constraints on the maximum deformation of FRP fishing boat under wave load:

$$\varepsilon_{max} \le [\varepsilon]$$

Through the genetic tools in Matlab software, a mathematical model is established, and the approximate optimal solution of the design variables of the FRP fishing boat is optimized. The parameters of the finite element model of the longitudinal-skeleton FRP fishing boat are modified in Patran, the balance is repeatedly adjusted, and the structure of the model is recalculated. strength., see Table 1.

2.6. Objective Function

Each optimization design algorithm is to achieve an expected goal through an optimal design solution. The expected goal is expressed in the form of an explicit or implicit expression function by using design variables designed by the optimization algorithm. Such a function is

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called an objective. A function can be written as. The setting of the objective function of the glass fiber reinforced plastic fishing boat in this paper can be considered according to the performance indicators of the total weight of the whole ship, economic cost, performance and safety. In order to achieve the best results from the optimization design, these performance indicators can be reasonably combined to form a multi-objective optimization problem, namely:

$$f(X) = (f_1(X), f_2(X), \ldots, f_p(X)) \tag{3}$$

Can also be simplified to:

$$\begin{aligned} & \min \quad f(X), X \in R^n \\ & s.t.\ g_j(X) \le 0, j = 1, 2, \ldots, J \\ & h_k(X) \le 0, k = 1, 2, \ldots, K \end{aligned} \tag{4}$$

For the optimization of the fiberglass reinforced plastic fishing boat studied in this paper, the light weight of the ship is mainly used to achieve the low energy consumption of the fishing boat and maximize its economic benefits. Therefore, based on the lightweight target of the FRP fishing boat, the weight of the whole ship of the 36.6 m FRP fishing boat can be used as the objective function of the optimal design. The expression of this function is:

$$F(X) = M_1 + \sum_{i=1}^{n_1} \rho_i V_i = M_1 + \sum_{i=1}^{n_1} \rho_i S_i t_i \tag{5}$$

Among them$M_1$is the quality of the whole ship equipment and crew; ρ_i is The density of the i-th hull member; V_i-The volume of the the hull component; S_i-The area of the i-th hull member; t_i-The thickness of the i-th hull member; n_i-The total number of ith hull members.

3. Whole Ship Optimization Results and Analysis

3.1. Optimization Calculation Results

Due to the small main dimensions of the glass fiber reinforced plastics fishing boat, the hull profile's curvature changes quickly, the space structure of the hull is complex, the number of hull structural members is large, and the freedom of design of each hat-shaped aggregate makes the size of the glass fiber reinforced plastics fishing boat's large number of parameters. It is difficult to achieve parameterized optimization of the entire ship. Therefore, in order to ensure the reliability of the direct calculation of the whole ship structure and effectively optimize the whole structure of the FRP fishing boat, this section aims at the lightest hull weight, and optimizes the longitudinal frame type FRP fishing boat based on the genetic algorithm. Table 1 shows the calculation results of the model before and after the comparison.

Table 1. Calculation results under the condition of droop limit before and after optimization

	Maximum equivalent stress (MPa)	Maximum shear stress (MPa)	Maximum deformation (mm)
Before	44.2	7.54	9.02
After	52.7	8.40	11.1
Allowable value	62	20	30

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According to the Cai-Wu failure criterion, the value of the Cai-Wu polynomial of the node where the maximum stress appears in the model after optimization is far less than the failure value of 1. The calculation result of the model meets the Cai-Wu failure criterion and no failure occurs.

4. Conclusion

I Based on the optimization process and results of the hull structure of the 36.6 m longitudinal frame FRP fishing boat, It can be obtained from the calculation results that the thickness of the hull shell, the main deck and the upper deck is reduced, which not only meets the allowable conditions for the strength of the whole ship structure, but also has a significant effect on the optimization of the light weight of the whole ship. The reduction in the thickness of the shell-shaped, main deck, upper deck, and cap-shaped aggregates on the superstructure is not obvious to the weight reduction of the whole ship, and it reduces the mechanical properties of the whole ship structure.

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References

[1] Fogel, L J. On the Organization of Intellect, UCLA. 1964: 321-342.

[2] Fogey L J, Owens. A J, Walsh. M J.: Artificial Intelligence through Simulated Evolution. 1966: 125-162.

[3] Fraser. A S. :Simulation of Genetic System by Automatic Digital Computers. Australian J. of Bio1, 1957,10: 484-491.

[4] Barricelli N A. Symbiogenetic Evolution Processes Realized by Artificial Methods. Methodos, 1957, 9(35-36): 143-182.

[5] Fang M C, Fang C C, Wu C H.: Prediction of design wave loads of the ocean structure by equivalent irregular wave approach. Ocean Engineering, 2007, 34(10): 1422-1430.