Research on a New Type of Catamaran with Shock-Absorbing and Energy-Saving Suspension Structure

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Abstract. Compared with traditional offshore tourism ships, the catamaran designed in this project adopts a suspension structure, which can bring shock absorption to the ship, so that the main hull has better stability and greatly improves the stability of the ship. It improves the comfort of passengers, and can better enjoy the fun of marine tourism; and a vibration power generation system is added to the suspension structure, which uses the kinetic energy generated by the undulating process of the ship to generate electricity, so as to achieve the effect of energy saving. At the same time, the catamaran designed in this project has two side bodies symmetrically located on both sides in contact with the water surface. The main body of the hull is suspended above the water surface under the support of the suspension system, which minimizes the contact between the main body and the seawater. The resulting frictional resistance reduces the use of energy, thereby achieving the effect of energy saving.

Keywords: Ships; Shock Absorbing Structures; Modeling.

1. Introduction

1.1 Research Background

In recent years, with the rapid development of my country's economy, science and technology and industrial level, people's demand for marine tourism has gradually increased, and the performance requirements of ships required for tourism are developing towards convenience, high performance and comfort. In this context, offshore ship tourism projects have been increasing, bringing people a variety of travel experiences. However, due to uncontrollable factors such as waves and sea breezes, the hull is violently turbulent, which brings poor travel experience to tourists. . Therefore, finding a comfortable, energy-saving and stable new type of tourist ship is an effective method to improve the current tourists' offshore tourism experience and increase the diversity of offshore tourism and entertainment.

1.2 Research Significance

The invention adopts a catamaran structure, and the catamaran has more advantages than a monohull, with a wide layout and good stability, and is suitable for small ships [1]. Compared with the monohull, the suspended structure catamaran is mainly composed of the main ship on the water and the side bodies symmetrically distributed on the hull. On the one hand, the catamaran designed in this project has good seaworthiness and is more stable than the monohull; on the other hand, the wave-making resistance and frictional resistance are small. The connection between the main body and the side body includes a support and shock absorption structure. The support structure is connected to the main body and the side body through the shock absorption structure, which can improve the comfort of passengers during sailing, and reduce the risk of severe bumps or even subversion in severe sea conditions. , and combine the suspension structure connecting rod with the piezoelectric energy recovery device and the permanent magnet power generation device, and use the Faraday electromagnetic induction principle to convert the vibration energy into electrical energy, thereby improving the energy utilization rate.

With the rapid development of high-speed passenger transport at sea, catamarans are generally favored due to their large deck area, space and convenient luxury decoration, and have become the fastest-growing, most widely used and most built high-performance ships in recent decades. A sort of. The new suspension structure catamaran designed in this project is not only more stable and suitable for high-speed sailing than the monohull, but also has enhanced shock absorption capacity compared with the traditional catamaran, and reduces the damping and reduction caused by power generation. The vibration is organically combined to achieve the effect of both shock absorption and energy recovery.

2. Research Status and Methods at Home and Abroad

2.1 Domestic Research Status

In the early 1970s, China Ship Science Research Center began to conduct follow-up research on high-speed catamaran related technologies. In the mid-1990s, my country already had the technical ability to design and produce small waterplane area catamarans. In 2000 In 2009, Shantou Dayang Shipbuilding Industry Corporation designed and built my country's first small waterplane area catamaran - "Customs 201" boat, which filled the gap in my country's high-performance ship technology field in this field [2]. my country's wave-piercing catamaran design technology started in 1997. Beijing China Shipbuilding Dongyuan Technology Development Co., Ltd. independently developed and successfully delivered my country's first wave-piercing catamaran "Strait" in December 2005. No. In the military field, my country launched the Type 022 missile boat in April 2004, and by mid-2009, more than 80 had been launched or in service. In 2010, the largest all-aluminum alloy wave-piercing catamaran "Dongyuan 01" in China, designed by No. 701 Institute of China Shipbuilding Industry Corporation and built by Wuchang Shipbuilding Industry Co., Ltd., was delivered [3]. At present, the domestic technology in the field of high-speed catamarans and their modifications tends to be mature. However, due to domestic economic and market constraints, the number of various types of high-speed catamarans, especially civilian models, is still limited, and the current domestic market only accounts for less than 10%. , the domestic development prospects are broad.

2.2 Current Status of Foreign Research

In the 1960s, the modern catamaran was born abroad. The catamaran is a new type of ship with high technology, high added value and high performance. This type of ship has excellent seaworthiness and remarkable rapidity. It has many advantages such as good stability, large deck area, strong vitality, easy control of underwater radiated noise, and easy parallel docking. In 1973, the United States took the lead in building the world's first small waterplane area catamaran "Camarino" [4]. Following the United States, some developed countries also have a strong interest in the development of catamarans, and have carried out a lot of basic theoretical research and model test technology for the development of this new type of ship. Catamarans have been further developed since the mid-1980s. In 1985, Japan built the world's largest small waterplane area catamaran at that time, the 3000-ton offshore operation test ship "Ocean". In 1991, the United States also built a 3,400-ton large-scale small waterplane area catamaran "Victory" class. In the military field, since the Australian Navy first pulled the catamaran from the shopping mall to the battlefield in the East Timor peacekeeping operation in 1999, the advantages of the catamaran in force projection and logistics support have been known to the world. It even decided to deploy more than 100 catamarans worldwide. Since the high-speed catamaran market became active, the international high-speed catamaran market has developed rapidly. Figure 1 shows the wave-piercing catamaran of China's "Shanghai"

Figure 1. China's "Shanghai" wave-piercing catamaran

At present, the research on catamaran is relatively mature, and the research on improving the riding comfort of civil catamaran is the hot spot and difficulty in current catamaran research. Ship stability is one of the most important properties of a ship. Due to the characteristics of the ship type, the catamaran has a large stability reserve, and has important application value in military ships and civilian ships [5]. Compared with the traditional catamaran structure, the new type of shock-absorbing suspension low-consumption catamaran studied in this project adopts a movable side body connection structure, which can not only make the main body more stable, but also use electromagnetic induction to absorb the riding time by recovering the hull energy. The generated mechanical vibration is converted into electrical energy, which can effectively alleviate the loss caused by vibration [6]. Feed back to the thrusters or for passenger use.

3. Design Scheme of Suspended Structure Catamaran

The suspension structure catamaran studied in this project is equipped with vibration power generation equipment and shock absorption system to optimize the traditional ship to achieve the purpose of shock absorption of the main body of the ship and improve energy utilization. The main researches are as follows:

3.1 Design of Ship Shock Absorption System

The ship suspension shock absorption system is the whole support system composed of the power generation device and shock absorber between the main hull and the side body. The suspension system plays the role of supporting the main hull, improving the ride comfort, and generating electricity at the same time. When designing the new suspension system, this project draws on the shock absorption system of the existing high-end car. Under the control of the computer, the crank of the shock absorber is connected The rod mechanism is driven by a servo motor, which directly converts the motor from rotary motion to bottom-up linear reciprocating motion, forming simple harmonic excitation [7]. A new type of marine suspension system is designed according to the motion characteristics of the ship during the running process.

3.2 Design of Power Generation Using Ship Vibration

During the normal operation of the ship, due to various external natural conditions such as the operation of the main engine, the design of the hull, and the undulation of the hull caused by the waves, the hull of the ship will vibrate under the actual working conditions. In response to this phenomenon, we installed permanent magnet vibration power generation equipment on the suspension structure link between the main hull and the side body of the catamaran. The permanent magnet linear motor uses a brushless DC linear generator, which has a high power density. and energy density. Several permanent magnet linear generators are placed in the slot. The permanent magnet linear generator is composed of shaft extension ends, magnets, springs, coils and casings. Connected with two springs, the mover is in a suspended state [8]. This design can fully recover the energy

generated by the hull vibration. In addition, at the connection between the suspension link and the side body, considering that the pressure increases with the Different motion states vary greatly. This project plans to design a piezoelectric power generation device for simultaneous energy harvesting. The piezoelectric energy harvesting technology has application reliability in complex traffic environments [9], which will greatly improve the efficiency of energy recovery.

The figure below shows a piezoelectric energy recovery device, which consists of ventilation holes, magnetic suspension permanent magnets, coil windings, fixed permanent magnets, and new springs. The device is designed to use Faraday's law of electromagnetic induction to generate induced electromotive force. transformation and control. When the hull is running, the pressure generated by the vibration of the suspension structure rod causes the magnet to cut the magnetic field lines to generate electric energy and store it in the battery under the main hull. At the same time, because part of the mechanical energy of vibration is converted into electrical energy, part of the energy and impact of vibration is reduced, and it can also play a role in reducing vibration to a certain extent.

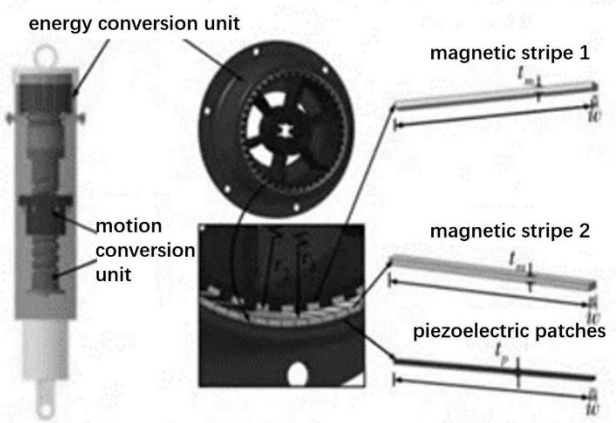

Figure 2. Piezoelectric energy recovery device

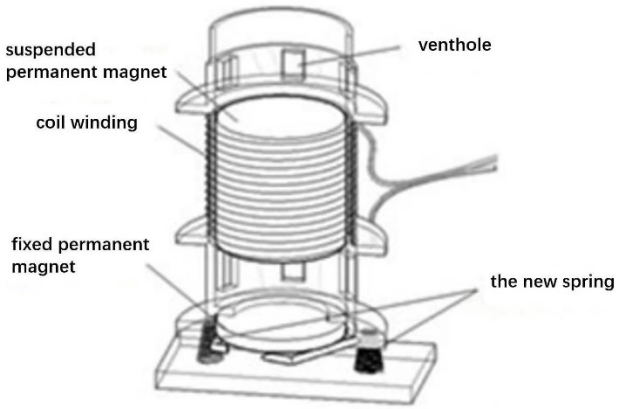

Figure 3. Permanent magnet vibration power generation device

3.3 Design of Main Hull Steering Control System

The catamaran designed in this project plans to use a water jet propulsion device, which is located behind the two side hulls and is responsible for the overall propulsion and steering of the hull. The water jet propulsion device usually consists of a water inlet channel, a propulsion pump, a nozzle and a control mechanism. It has the advantages of high propulsion efficiency, excellent anti-cavitation performance, good maneuverability, and attachment resistance. The basic principle is to use the propulsion pump to spray water flow. The reaction force drives the marine vehicle to move forward,

and it has been widely used in the field of ships, especially on high-speed ships and military ships [10].

This project plans to design a set of power plant and control system based on water jet propulsion. The system mainly includes: a pair of water jet propulsion devices with vector nozzles, and a corresponding developed set of control system. Highly integrated design, easy for the driver to operate.

3.4 Technical Route of Project Research

(1) According to the research direction of this project, consult domestic and foreign literature on catamaran, suspension system and vibration power generation device;

(2) Draw the essence of relevant literature, carry out structural design according to this project, and use SolidWorks software for model construction;

(3) After the model is built, use the motion function of Solidworks software to perform motion simulation, and use starccm+ software to perform simulation analysis of the external flow field, and optimize the model based on the above results.

(4) After establishing the corresponding physical model, design relevant experiments, carry out physical model testing, and then revise the design scheme after obtaining relevant data.

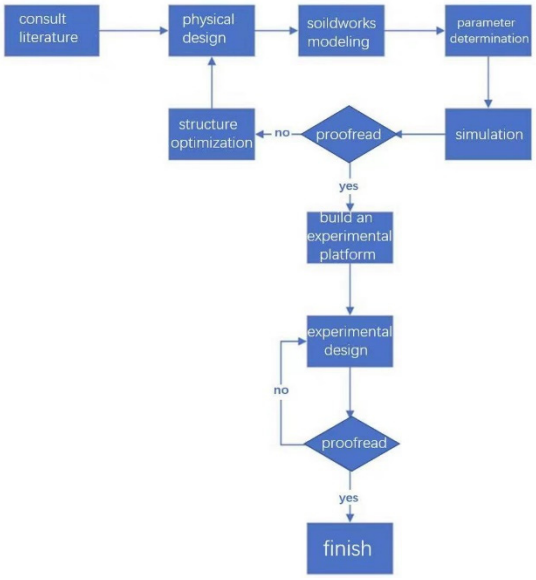

Figure 4. Flow chart of project research technology route

4. Structural Design and Result Analysis

4.1 Feasibility Analysis of Shock Absorption System

The new type of suspended catamaran uses electromagnetic shock absorbers to complete the shock absorption effect on the main hull. The electromagnetic shock absorber is adjusted by the electromagnetic damping control system by the central control system, and the dynamic hull is connected to a variety of sensors to detect various conditions such as the water surface state. The sensor can transmit real-time data to the central electronic control system, the central electronic control system accepts and processes the signal, and the control unit sends out a pulse signal to control the coil voltage, change the particle arrangement, and change the damping coefficient to control the electromagnetic shock absorber to respond quickly. , to maximize the cushioning effect and provide passengers with the most comfortable riding experience, and the technology is feasible.

4.2 Feasibility Analysis of Vibration Power Generation

The normal operation of the catamaran causes its suspension link to swing, and a piezoelectric energy recovery device is installed at the connecting part of the suspension link and the main hull, and the device is used to recover and utilize the vibration energy. The piezoelectric energy recovery device is composed of ventilation holes, magnetic suspension permanent magnets, coil windings, fixed permanent magnets, and new springs. The permanent magnets of the energy recovery device are connected. When the catamaran is running, the pressure generated by the vibration of the connecting rod of the suspension structure causes the permanent magnet to cut the magnetic field line, and the Faraday electromagnetic induction is used to convert the vibration energy into electrical energy, which is stored in the battery. The method can effectively convert vibration energy into electric energy, improve the efficiency of energy recovery and utilization, and is technically feasible.

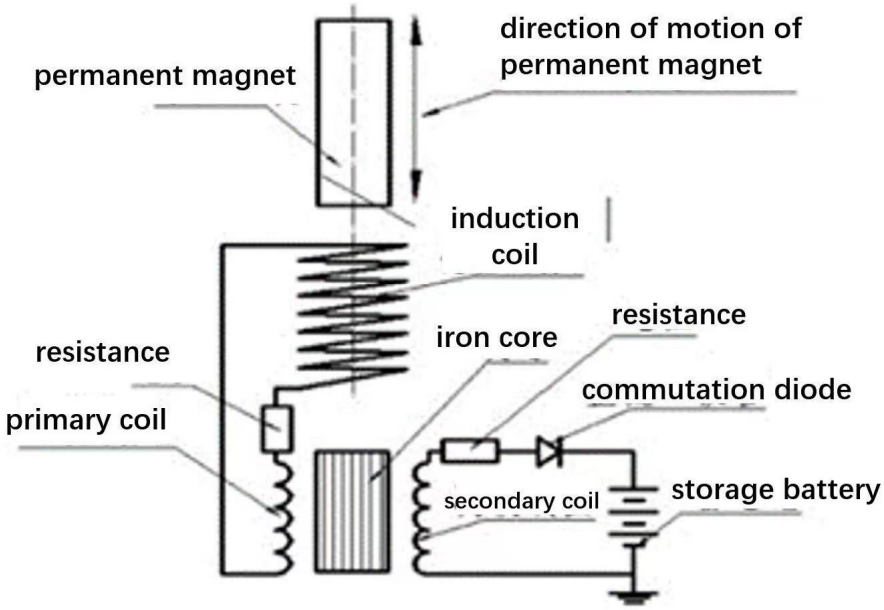

Figure 5. Schematic diagram of permanent magnet vibration power generation device

4.3 Modeling Results Display

At present, the members of this project have carried out the preliminary modeling of the catamaran after the process of collecting a large number of documents and combined with the design concept of this project. The modeling results are shown in Figure 6:

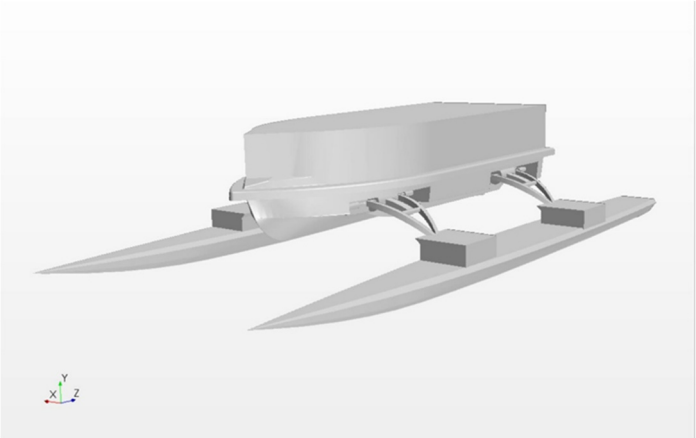

Figure 6. Schematic diagram of the preliminary design of the catamaran

After obtaining the 3D model, we use starccm+ software to simulate the external flow field of the catamaran, select water as the working fluid, set the flow rate to 10m/s, and its surface force distribution is shown in Figure 7 below:

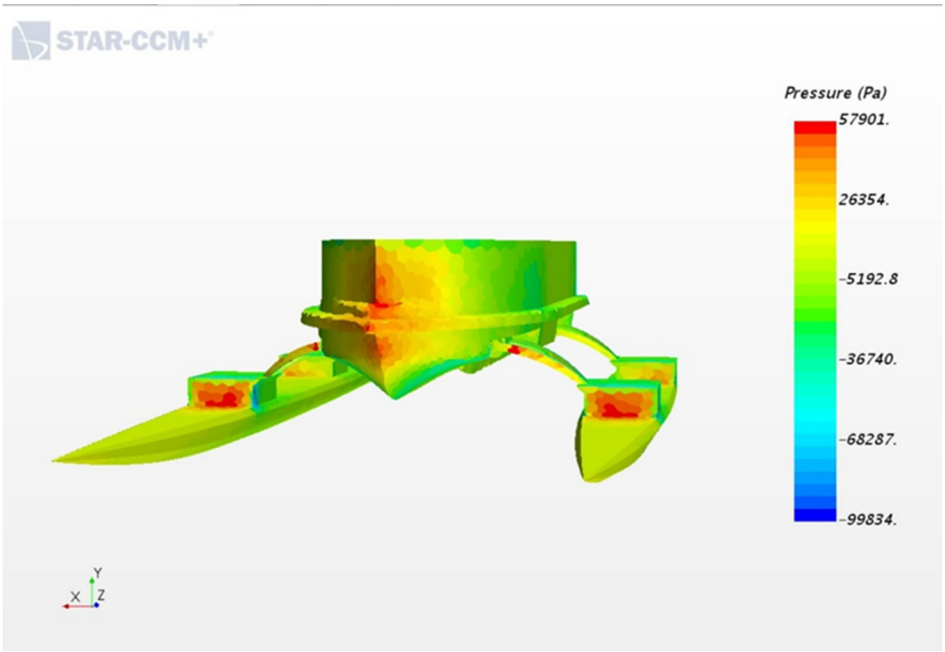

Figure 7. Schematic diagram of simulated force distribution of catamaran outboard flow field

From the above figure, we can see that the catamaran has three parts where the stress is concentrated, namely the bow, the connecting rod, and the connecting device between the connecting rod and the side body. The above three parts bring more resistance to the catamaran. It has a large impact and will increase wear and tear. Therefore, in the next step, we will optimize the structure of the above parts. In addition, we also obtained the velocity of the water plane fluid through simulation experiments, as shown in Figure 8 below:

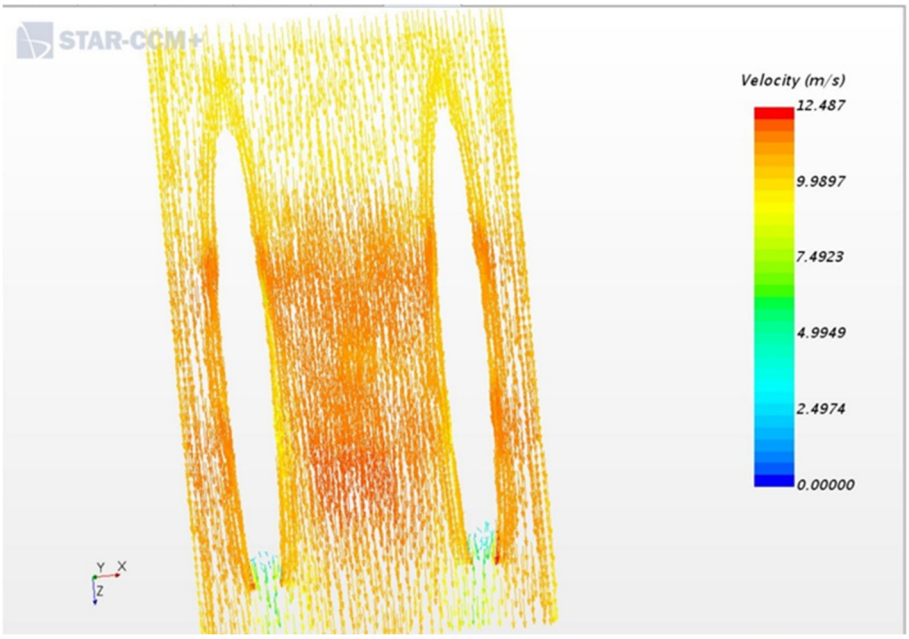

Figure 8. The velocity of the fluid on the waterplane surface

5. Conclusion

This project designs a new type of shock absorption system by combining shock absorbers with suspension structure links, which improves the comfort of boat rides. Piezoelectric material is used at the connection between the side body and the connecting rod, and a permanent magnet power generator is installed inside the suspension structure to recover the kinetic energy generated by the fluctuation to the greatest extent and achieve the effect of energy saving. The suspension structure allows the main hull to be suspended on the water surface, which not only reduces the frictional resistance of the main hull, but also reduces the corrosion loss of the main hull caused by seawater and reduces the maintenance cost of the catamaran. The organic combination of power generation and shock absorption, the combination of damping and shock absorption brought by power generation, improves energy utilization efficiency, and reduces the wear of shock absorption parts, which has a positive impact on energy conservation and emission reduction.

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