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

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Abstract. At present, the suspended structure catamaran is composed of the main ship on the water and the side bodies symmetrically distributed on the hull. Such a structure avoids the direct contact of the main ship with the water surface, and has good stability. In this paper, a shock absorption system for ships is designed. It is undertaken by the double wishbone independent suspension system, which includes the upper wishbone, the lower wishbone, the bracket, the shock absorber and other components. The double wishbone suspension system is used in the shock absorption of this project, which can well cope with the huge impact brought by the waves. The 3D model of the hull is modeled, and the external flow field simulation of the catamaran is carried out by using starccm+ software, and the design optimization of the tail structure and thruster is realized.

Keywords: Electromagnetic Suspension; Double Wishbone; Electromagnetic Actuator; Energy-Saving Shock Absorption.

1. Project Background and Research Significance

1.1 Research Background

In recent years, with the rapid development of China's economy, technology and industry, 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, the number of offshore ship tourism projects has increased continuously, bringing people a variety of travel experiences. However, due to uncontrollable factors such as waves and sea wind, the hull is violently turbulent, bringing tourists a poor travel experience. 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. Compared with the traditional offshore tourism ships, the catamaran designed in this project adopts a double wishbone independent suspension system, which can bring shock absorption to the ship, so that the main hull has better stability and is extremely stable. It greatly improves the comfort of passengers and can better enjoy the fun brought by marine tourism. 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[1].

Wave energy is the richest among all kinds of marine energy. Although wave energy is not easy to collect and is unstable, its total amount is considerable and it is always generated at sea. It can be seen everywhere[2]. It is more convenient and efficient for ships to supply electricity through wave energy generation. We designed wave-undulating inertial power generation. With the development of the times, just sailing at sea can no longer meet people's needs. Beautiful hull, easy-to-maneuver ships, comfortable and quiet sightseeing environment, lower cost of going to sea and ship maintenance have become the direction of breakthroughs.

1.2 Research Significance

The invention adopts a catamaran structure, the catamaran has more advantages than a monohull, the layout is wide, the stability is good, and the catamaran is suitable for small ships. 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[3]. The azimuth propeller is suspended by the link at the rear of the main hull to provide power, which avoids the main ship directly contacting the water surface as much as possible. On the one hand, the catamaran designed in this project has good seaworthiness and is more stable than the monohull, and adopts the azimuth propeller, which makes the ship more maneuverable; on the other hand, the wave resistance and friction resistance are small. The connection between the main body and the side body adopts the double wishbone independent suspension system on the existing car. This technology is relatively mature and has a simple structure, which can improve the comfort of passengers during sailing, and reduce severe turbulence and even in severe sea conditions[4].

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. Double-wishbone independent suspension has been widely used in cars because of its good shock absorption performance. It combines the movement characteristics of ships floating up and down under the influence of waves on the sea and the double-wishbone independent suspension can fit the sea surface[5]. Compared with ordinary ships, the double wishbone independent suspension is applied to the ship, which enhances the shock absorption capacity. The direction of the propulsion force of the ship's traditional thrusters is fixed, and the magnitude of the propulsion force depends on the speed of the engine. The course of the ship is mainly achieved by the rudder. When the speed of the ship is low, the rudder effect will be significantly reduced, and the maneuverability of the ship will also be significantly reduced. In addition, the traditional propeller also has problems such as complex structure, high cost, and inconvenient maintenance and repair. In view of these problems, we choose the azimuth rudder propeller propulsion system[6].

1.3 Research Status at Home and Abroad

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, China technically had the ability to design and produce small waterplane area twin hulls. In 2000, Shantou Dayang Shipbuilding Industry Corporation designed and built China'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.



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

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". 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[7].

2. Energy-saving Suspension Calculation Algorithm

2.1 Dynamic Model

For the convenience of studying the problem, the catamaran suspension system is simplified without affecting the characteristics of the suspension system. When the vertical vibration of the ship is mainly considered, the independent suspension system of a catamaran equipped with electromagnetic actuators and magnetorheological dampers can be equivalent to a two-mass two-degree-of-freedom system. The mechanical model is shown in Figure 2.

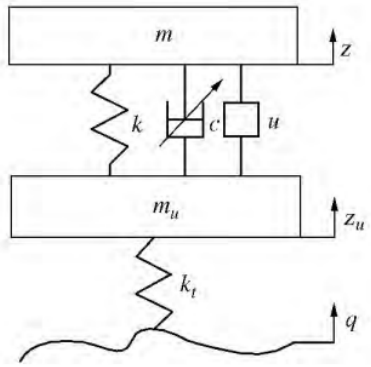


Figure 2. Two degrees of freedom catamaran model

In Figure 2: m is 1/10 of the car body mass, z is the displacement from the static equilibrium in the vertical direction, m_u is the mass of the road wheel, z_u is the displacement from its static equilibrium in the vertical direction, and k_t is The stiffness of the road wheel apron, c_t is the damping of the road wheel apron, q is the function of road roughness, q·is the rate of change of road roughness in the vertical direction, and us is the active control force including variable damping force and actuating force. Its kinetic equation is:

$$\begin{cases} m\ddot{z} + c(\dot{z} - \dot{z}_u) + k(z - z_u) + u_s = 0 \\ m_u\ddot{z}_u + c(\dot{z}_u - \dot{z}) + k(z_u - z) + c_t(\dot{z}_u - \dot{q}) + \\ k_t(z_u - q) - u_s = 0 \end{cases}$$

2.2 Analysis and Calculation of Composite Structure Characteristics

When the main force F of the electromagnetic suspension is opposite to the relative velocity v of the damper (that is, the relative movement speed between the piston rod and the cylinder of the magnetorheological damper), the maximum and minimum values of the main force F are:

$$\begin{cases} F_{max} = F_a + C_b v \\ F_{min} = 0 \end{cases}$$

When the main force F of the electromagnetic suspension is in the same direction as the relative velocity v of the damper, the maximum and minimum values of the main force F of the composite structure are:

$$\begin{cases} F_{max} = F_a \\ F_{min} = 0 \end{cases}$$

Taking the relative speed of the damper as the reference point, the main force of the electromagnetic suspension of the parallel structure can be adjusted in two directions. A single magnetorheological damper can only be adjusted in one direction, while the passive suspension is not adjustable.

3. Structural Design of Suspended Catamaran

3.1 Design of Ship Shock Absorption System

The shock absorption system of the ship designed in the project is undertaken by the double wishbone independent suspension system, which includes the upper wishbone, the lower wishbone, the bracket, the shock absorber and other components. Most of the double-wishbone structures are often used in SUVs or pickup trucks[8]. When used in cars, the wheels can stick to the ground well, making the vehicle more maneuverable. The two triangular rocker arms have excellent torsional strength and Lateral stiffness. Combined with the movement characteristics of the ship, a double-wishbone shock-absorbing suspension system suitable for use on ships is designed. The double wishbone suspension system is used for the shock absorption of this project, which can well cope with the huge impact brought by the waves [9].

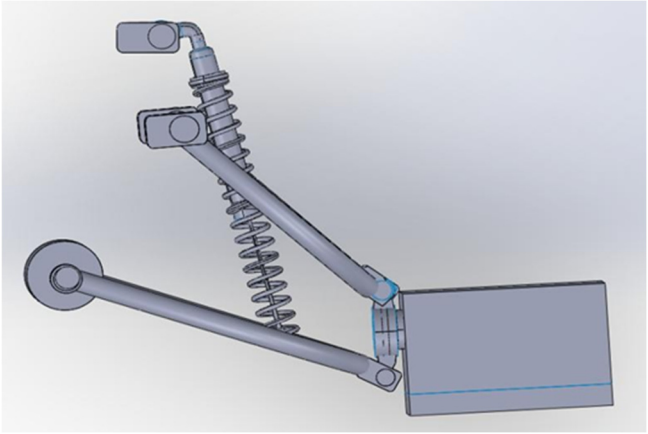


Figure 3. Double wishbone independent suspension

3.2 Design of Floating Body Vibration Power Generation

During the normal driving 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 waves, the hull of the ship will vibrate under actual working conditions. Figure 4 below shows the permanent magnet power generation[10]. The device is composed 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, and the single-chip microcomputer realizes the collection, conversion and control of voltage. When the hull is running, the floating bodies on both sides will float up and down when encountering vibration, and the high-quality suspended permanent magnets inside the permanent magnet vibration generator will move up and down due to the action of inertia, so that the magnets move up and down to cut the magnetic field lines to generate electric energy and then store it in the main body. in the battery under the 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.

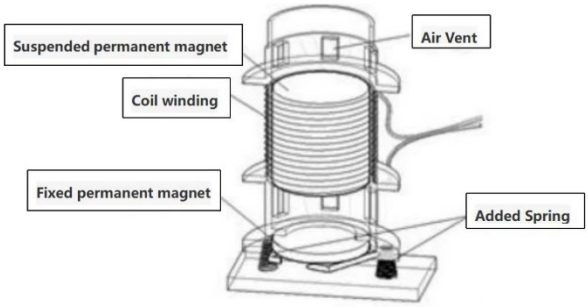


Figure 4. Permanent magnet vibration generator

3.3 Design of Azimuth Rudder Propeller Ship Propulsion System

The ship's azimuth rudder propeller propulsion system is also called "Z-shaped propeller". Named for the zigzag arrangement of the shafting in the pod. This kind of propeller places the Z-shaped shafting and the deflector propeller in the pod, and the propeller is suspended under the stern of the hull by the connecting rod and protrudes into the water [11].

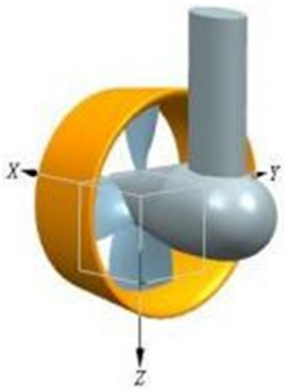


Figure 5. The azimuth rudder propeller

At the same time, the azimuth rudder propeller propulsion system uses the hydraulic pump to drive the worm gear to rotate to achieve 360° horizontal rotation. The direction of the thrust can be changed at will according to the change of the ship's position, which greatly improves the maneuverability and maneuverability of the ship [12]. In addition, since the relevant transmission system is arranged in the pod, a lot of space in the hull is saved, which greatly increases the flexibility of ship design, construction and use. The 3D model of the ducted propeller is shown in Figure 6.

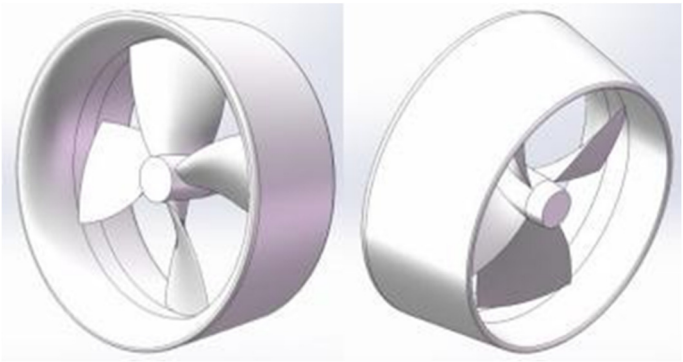


Figure 6. 3D model of the ducted propeller

4. Result Analysis of Suspended Structure Catamaran

4.1 Feasibility Analysis of Damping System

The double wishbone suspension system is a double crank mechanism with a shock absorber. The shock absorber has good compression and keeps the floating body level when it moves up and down. Structurally, the double wishbone suspension is arguably the strongest independent suspension. We all know that the triangle is the most stable geometric shape. The upper and lower A-arms of the double wishbone suspension have a stable structure similar to the triangle and have sufficient strength. (Sports talent of double wishbone independent suspension) The double crank mechanism can make the floating body always in close contact with the water surface, so that the floating body will not roll. The shock absorbers carry the weight of the entire main hull and allow the A-arm to bounce back powerfully when it swings up. When there are waves, the double wishbone suspension system can well absorb the hull undulations caused by the waves[13].

The double wishbone suspension system is widely used in automobiles. The technology is relatively mature, the structure is simple, and it is easy to maintain. It can absorb the water surface fluctuations caused by waves. It is feasible to apply this technology to the catamaran shock absorption suspension system.

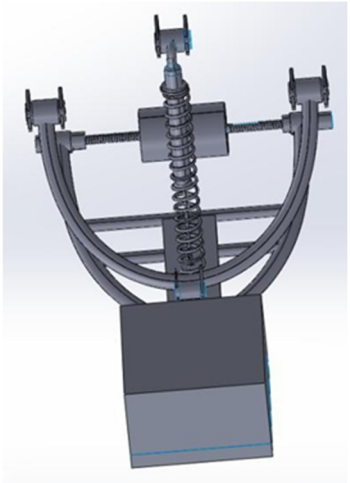


Figure 7. Double wishbone independent suspension

4.2 Implementation Analysis of Floating Body Swing Power Generation Device

The normal operation of a catamaran causes its float to oscillate up and down with the waves. When the ship is running normally, the floats on both sides of the catamaran will swing up and down due to the action of the waves. The permanent magnets in the power generation device have a large mass, and the inertia is large during the up and down swinging process, which makes the permanent magnets cut the magnetic field lines. , using Faraday electromagnetic induction to convert vibration energy into electrical energy[14].

In order to solve the problem that the output voltage of the generator is unstable due to the different fluctuations of each time, the permanent magnet vibration generator is connected to a voltage stabilizing circuit. The voltage stabilizing circuit consists of a first resistor to a fourth resistor and a first capacitor to a fifth capacitor. , voltage regulator chip, operational amplifier, first voltage regulator tube to third voltage regulator tube, inductor and rectifier, the third point in the circuit plays a protective role in the operation of the entire system, making the circuit when the voltage is unstable to maintain sufficient stability, the circuit is composed of a small number of electronic components, and the cost is low [15].

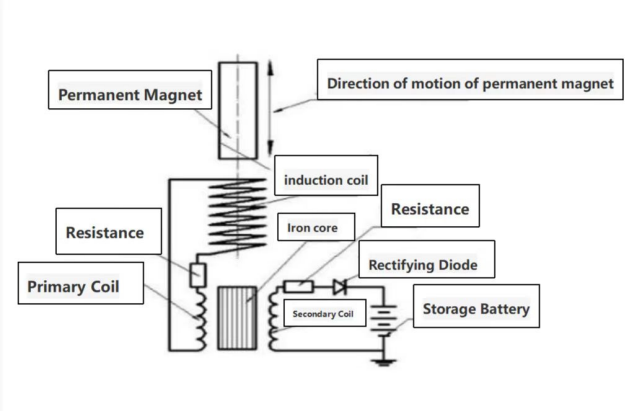


Figure 8. Permanent magnet vibration power generation device

5. Modeling Analysis of Catamaran

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 9:

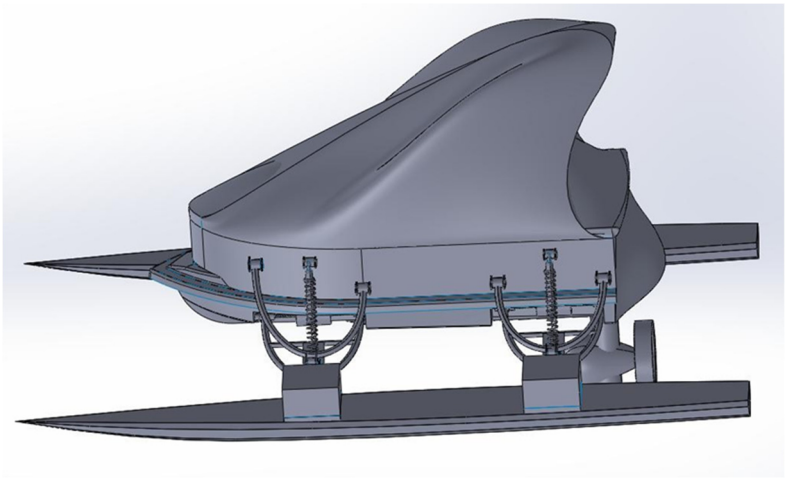


Figure 9. Modeling for a catamaran

After obtaining the three-dimensional 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 the force distribution on its surface is shown in Figure 10 below:

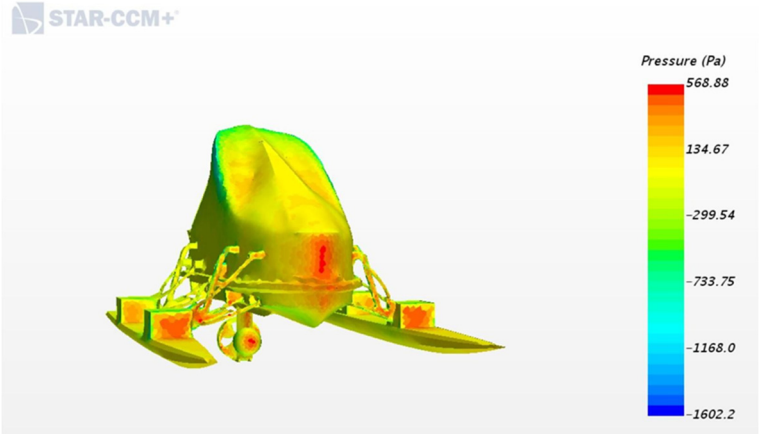


Figure 10. The simulated force distribution of the outboard flow field of the catamaran

From Figure 10 above, we can see that the catamaran has four stress-concentrated parts, which are the front end of the propeller, the bow, the connecting rod, and the connecting device between the connecting rod and the side body [16]. The above four parts have resistance to the catamaran. Bring a greater impact, while increasing wear and tear. Therefore, in the next step, we will optimize the structure of the above-mentioned parts [17]. In addition, we also obtained the velocity of the water plane fluid through simulation experiments, as shown in Figure 11 below:

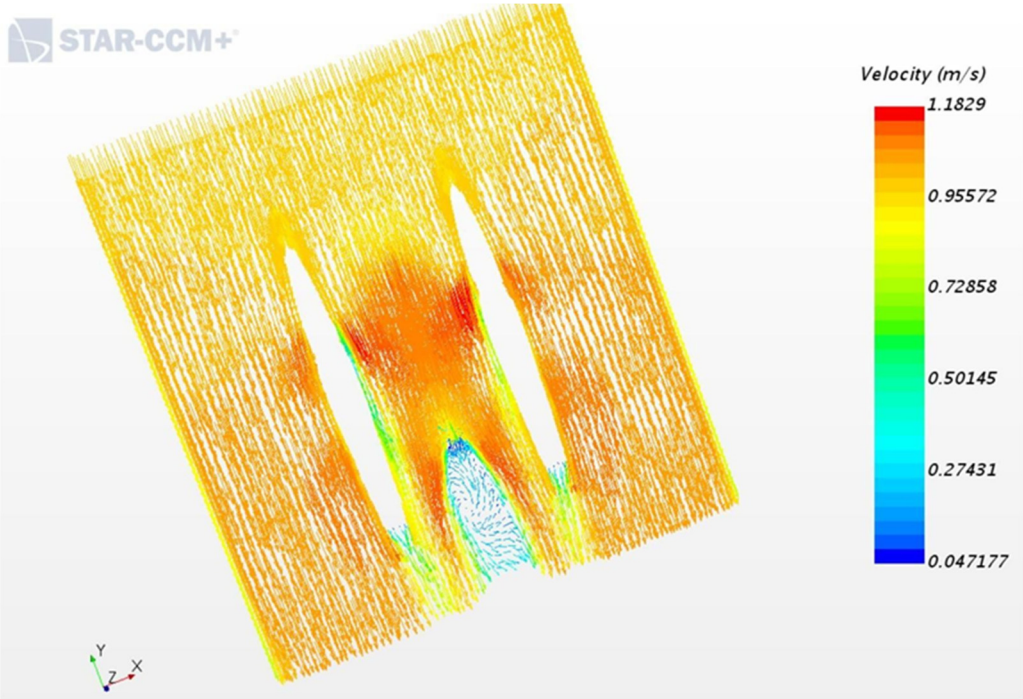


Figure 11. The velocity of the fluid on the waterplane surface

6. Conclusion

The author draws on the mature double wishbone independent suspension system for shock absorption. It combines wave power generation with the vibration inertia of the floating bodies on both sides to generate electricity. An azimuth thruster is installed behind the main hull to increase the manoeuvrability of the hull. 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.

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