Virtual Test and Evaluation of Ships Overall Design Scheme Based on CATIA

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Abstract. To evaluate the level of the ship design scheme, several major problems during the ship design virtual test and evaluation process have been studied and technology developed by CATIA virtual platform. Including: fast virtual test model for ship hull surface modeling, virtual modeling and assembly for ship equipment based on knowledge-based engineering, and virtual evaluation combined with ergonomics of the ship design scheme. The cost of the large physical test can be reduced by using virtual test and evaluation to evaluate the ship design scheme. The test cycle is short, it is beneficial to improve the development and progress of the level of the ship design technology, and a reliable and practical way to test and evaluation of ship optimization design is presented.

Introduction

With the development of the ship design level and the improvement of the ship design requirements, there is an increasing need for the industry to verify the ship design virtual test and evaluation process. Virtual test verification refers to the use of virtual reality and computer simulation to build a digital test environment and evaluate the level of ship design [1]. Virtual test verification can overcome the shortcomings of large-scale physical test, such as high cost and long test period, and contribute to the constant development of the technical level of ship design. [2].

At present, the research on the application of virtual test verification technology in ship product is gradually emerging. The concept and method of virtual test verification technology have been initially approved. Based on the overall design plan of a fishing vessel, the main problems in the virtual test of design process of the fishing vessel are studied and in this paper. Taking CATIA as a virtual platform, this paper studies the rapid establishment method of virtual model of 3D hull surface, virtual modeling and assembly test of ship equipment based on knowledge-based engineering, and the virtual verification of the ship design scheme based on ergonomics, and provides a new people oriented perspective in the hope of providing useful reference for the design of the ship.

Rapid Virtual Modeling of Hull Surface

The rapid and accurate modeling of the hull surface is the basis for the virtual test of the ship. Because of the large number of data points that describe the hull lines, each data point contains X, Y, Z three-dimensional coordinates. Whether it is obtained from a line chart or data points table, or data points importing into CATIA software is time consuming and laborious. Therefore, this experiment developed a data points extraction program based on hull lines using VBA, the interface is shown in Figure 1. Main idea is: the vertical position and half-width value are extracted directly from the half-width waterline, and then the half-width waterline is divided into the contour waterline with half height and the unequal height line. For the equivalent width of the water line, the unified Z value; for non-contour line to set the reference point way to automatically extract the actual height of each point as the Z value, and then regenerate using a three-dimensional spline with the extracted longitudinal, horizontal, vertical coordinates Finally, the line containing the complete data is interpolated at the custom spacing and saved in the desired format.
The hull surface was established in CATIA by using points to lines and wiping lines. This experiment uses CATIA's GSD_PointSplineLoftFromExcel data file to run the import data points. The essence is to draw CATIA by Excel macro. After completion of distribution points can be directly connected [3]. Figure 2 is the result of the introduction of data points in CATIA for a fishing boat. Figure 3 is a virtual model of the hull surface.

Figure 1. Program interface.  Figure 2. Results after importing points.  Figure 3. Virtual model of.

**Ship Equipment Virtual Modeling and Assembly**

**Ship Equipment Virtual Modeling Based on Knowledge-based Engineering**

According to the characteristics of various types of ship design, the equipment configuration has certain regularity. Therefore, for a particular ship, it is reasonable to make a pre-design of the ship's equipment. With reference to the standard parts library, building a ship equipment library can accomplish this task well. When designing, if the equipment model exists in the library, simply call the existing equipment model as the design basis and modify the main parameters to regenerate the model so that the ship equipment can be quickly modeled. If not, solid modeling can be performed and added to the device library for later use by designers.

Based on the CATIA knowledge engineering module, this experiment established a three-dimensional parametric ship equipment library by using secondary development technology to realize the rapid establishment and modification of the ship equipment virtual model with the main control parameters as the main body [4]. Additionally, through the reasoning of the default design rules to achieve the purpose of the auxiliary decision-making, the design rules are linked with the design parameters to realize the intelligent modeling of ship equipment. By setting the inspection standards for the model, the preliminary inspection of the design scheme is carried out so as to reduce the design errors and make the design tend to be reasonable. Figure 4 is a virtual model of roller-type winch based on knowledge engineering. It drives the design size in the form of design table, and realizes rapid modification and regeneration of the model.

**Assembly Design and Real-time Rendering**

There are a large number of standard parts for the assembly of ship products, as well as a large number of special equipment for different types of vessels. For the assembly of standard parts, it can be accurately positioned with the contact, consistency and other constraints [5]. Because of its layout and the diversity of surface shapes, special equipment for ships is often located by manual movement. However, this method is cumbersome and cannot control the movement distance in real time. In this regard, the following method is adopted. At the beginning of device modeling, X, Y, Z coordinates (based on a specific reference point such as station 0) are preset in the part document. In the assembly module, the X, Y and Z coordinates in the parts are extracted by the secondary development, and the parts are positioned in the corresponding position. Then the designer defines the fine-tuning, such as the constraints to fine-tune the assembly of the specific device. Figure 5 shows the effect of the assembly of the hull and the equipment. At this point, the virtual modeling and assembly of the hull and equipment has been completed. And it can be more close to the real effect with the application of CATIA material library. At last, the virtual sea scene is built in CATIA to complete the coordination.
of hull and sea scene and simulate the real scene to provide realistic feelings, intuitive evaluation and verification design for designers. Figure 6 shows the effect of the scene simulation.

Ergonomics-based Virtual Verification

Ergonomics mainly studies the rules of interpersonal relationship between people, machines and environment, and makes the parts of each part coordinated, so that the overall system can be optimized [6]. This test applies ergonomic theory to the virtual verification of ship design and the vision field of ship cabin and cabin maintenance space and personnel comfort assessment and passenger accessibility of double bottom manhole and internal construction maintenance accessibility analysis.

Virtual Human Modeling

Virtual human modeling is the basis of virtual verification. In the design and verification of ships, the coordination between human and ship verifiers is inseparable from the participation of virtual human [7]. The established hull, equipment and scene model are used as the virtual verification environment. And virtual human is used to be a link to simulate the normal state of the human body and to evaluate and feedback the design.

The virtual human model is invoked by CATIA in this experiment [8]. The size of the virtual human is set for reference to the national standard of Chinese adult human body size [9]. The virtual human modeling process is shown in Figure 7.

After building a virtual person, it is necessary to set the comfort of the virtual person [10], because the position of the virtual human joints and the "feelings" of the virtual human have not been defined. There are limits in human joints. And there are different levels of perception in different regions within the limits. So there's a point of comfort and discomfort. If the limit is exceeded, it will cause damage to the human body. According to the literature [11], the scope of the body's important activities and the comfortable posture of the body parts were set.

Virtual Verification of the Visual Field of Ship Cabin

The visual field of ship cabin is related to the safety, navigation and function of the ship. In ship design, it is necessary to consider whether the vision field of ship cabin can meet the expectations and requirements. The virtual experiment can be used to verify the visually [12]. The virtual human is placed in the cab and above the second deck. By controlling the rotation of the virtual head, we simulate the actual driving state, observe the squarely and the left and right field of vision, and verify whether the design is reasonable.

Figure 8-9 show the visual field of the virtual person on the left and right cabs of the cab and on the deck of the cab in a CATIA virtual environment. As can be seen from the field of vision, due to the opening of the windows on both sides of the front, left and right front view is obscured. Therefore, we should redesign the location and size of the window layout in the cab according to the reality.
Cabin Maintenance Space Verification and Staff Comfort Evaluation

The space of the fishing boat cabin is small, which often brings inconvenience to the layout and mainframe maintenance. Therefore, it is necessary to verify the cabin space and evaluate the comfort of the personnel. In the cabin of the fishing boat, the cabin is divided and the host model and the wrench model are established. The wrench model is later bound to the virtual human, as shown in Figure 10. The transparency of the outer plate of the corresponding part of the hull is set to be hidden so that it is easy to observe. The cabin virtual scene is shown in Figure 11.

In the cabin, the virtual person is adjusted to a predetermined position. Then two positions are designed: upright twist the top of the host screw and kneepad support to twist the bottom of the host screw. In both cases, it is analyzed whether the maintenance activities in the engine room are limited by the spatial distance and the comfort of the human body in the restricted working space.

(1) Maintenance at the top of the host.

As shown in Figure 12, according to the results of the space measurement and the color of the human body, the human body has greater margin in terms of comfort and workspace, and the personnel can accomplish the tasks more conveniently and comfortably.

(2) Maintenance at the bottom of the host.

As shown in Figure 13, there is a significant change in the comfort of the work space and of the human body due to changes in the posture of the human body and the space limitations of the fuel tank, bilge shell and mainframe. Due to its small range of activities in the left calf and ankle, it can be seen from the color of the corresponding parts in Figure 13 that it is in a rather uncomfortable posture, working for a long time and frequently. This may cause fatigue or injury to the corresponding parts of the maintenance personnel.

Double Bottom Manhole Connectivity and Internal Build Reachability Verification

The inner space of a ship's double bottom is very small, which will bring difficulties to the construction. Whether the construction personnel can smoothly enter the double bottom through the manhole, weld or build and maintain the steel plate of the hull is a problem that needs to be verified in
the design. A virtual double bottom model is built in the CATIA virtual environment, with a size of 600 x 800mm on the upper opening. In this environment, verify whether the virtual human can enter the inner double bottom through the manhole to do the actual operation, and the accessibility of the hands when the personnel operate. Mainly verify the following three working conditions: whether the virtual human can successfully crawl through the manholes, the virtual man crawls close to the side top of the double bottom and lies sideways near the top of the double bottom. Then, by setting the working status, we can analyze whether the staff can smoothly pass through the double bottom manhole, and whether we can smoothly weld the weld inside the double bottom. Figure 14 shows the availability of the virtual human through the manhole of the double bottom. It can be seen that there is no big obstacle to the virtual human being through the manhole. This shows that the size and position of the manhole are reasonable from the point of view of the human body.

Figure 15 and Figure 16 show that virtual people are trying to approach weld posture with crawl and lateral posture and verify whether the welding can be carried out smoothly. By using the hand contact surface function, the welding gun is prepositioned at the most corner to see whether the hand surface can reach the handle of the welding gun. If it is able to fit with the position of the handle, it is possible to do the welding operation. But it can be seen that there is a certain distance from the handle of the welding gun in the two postures. Therefore, it can be concluded that the actual welding from the bottom of the double bottom is difficult to construct, and the design plan should be considered to make the design feasible and operable.

![Figure 14. Manhole passed. Figure 15. Crawl close to the seam weld. Figure 16. Laterally close to the seam weld.](image)

**Summary**

Based on the overall design plan of a fishing vessel, the main problems in the virtual test verification process of the whole fishing vessel are studied and developed in this paper. Taking CATIA as a virtual test platform, the methods of rapid establishment of three-dimensional hull surface virtual model, the virtual modeling and assembly test of ship equipment based on knowledge engineering and the virtual verification of the ship design scheme based on ergonomics are studied. According to the Chinese adult body size, a virtual human model is established, which is used for performing virtual experiments to verify the comfort of the real human body in the corresponding posture. At the same time, a virtual scene such as hull, cab, cabin, double bottom and sea condition was established, and the virtual person was imported for field of vision verification, space verification, operational verification and comfort verification. Through the virtual experiment, the visualization, feedback and evaluation of the design intent of the ship are realized, which provides a new perspective for the people-oriented design of the ship. It is hoped that this can provide a useful reference for the design of the ship.

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