

Design and Structural Analysis of the ROV Framework Based on ANSYS

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Abstract: This paper discusses the framework design and implementation of underwater robot (AUV / ROV). With the increasing importance of Marine resources and the complexity of Marine environment, underwater robots, as an important technical means, play an increasingly important role in the field of Marine development and utilization. This paper first summarizes the research significance of underwater robot, as well as the research dynamics at home and abroad, which provides the background and basis for the subsequent research. First, the main body framework is modeled with Solidworks, and then ANSYS finite element analysis is used to analyze the strength and static force of the ROV ontology framework, and then the equivalent force map and equivalent elastic strain map is obtained. Research samples are provided for subsequent studies with other carrying devices.

Keywords: Underwater robot; ROV; static force analysis

1. Introduction

In underwater robot framework design, significant progress has been made at home and abroad. Foreign research started earlier, and has accumulated many years of research results. For example, deep-sea divers developed by Woods Hole Oceanographic Institution in the United States, such as Alvin, Jason, and Sentry, have played an important role in deep-sea exploration and exploration. The European Marine Research Center in Europe has also developed a series of unmanned underwater robots, which are widely used in areas such as Marine environmental monitoring and Marine resources exploration^[1]. These achievements show the profound strength and technical accumulation of foreign countries in the framework design of underwater robots.

At the same time, although the domestic research started late, it has also made great progress in recent years. Some research institutions and enterprises have successfully developed underwater robots with their own intellectual property rights, and have achieved good results in practical application. These underwater robots have made great innovations in structural design and control system, which reflects the rapid development of underwater robot technology in China.

In general, the research on underwater robot framework design at home and abroad is deepening, and the technical level is also constantly improving. In the future, with the increasing demand of deep-sea resource development and Marine environment monitoring, the application prospect of underwater robots will be broader, and related research will be more active.

2. Research content

Underwater robot is one of the most widely used underwater operation equipment, underwater robots are generally divided into two types: cable less robot (AUV) and cable robot (ROV). The AUV has cable less characteristics, which means it can be more flexible and not limited by cables. Secondly, AUV has the ability to control independently^[2]. It enables self-navigation and decision-making based on preset programs or real-time environmental information, which allows the AUV to work independently in a complex and changeable underwater environment. In addition, the AUV can be equipped with a variety of sensors and measuring instruments, such as sonar, cameras and chemical analyzer. With these sensors and instruments, the AUV is able to collect a variety of data in real time, such as temperature, pressure, flow speed and seabed topography, providing researchers with comprehensive and accurate information. Finally, the AUV also has intelligent processing capabilities.

It can adaptively adjust the data sampling frequency and sampling area according to the real-time environmental changes to achieve efficient and accurate data collection^[3]. The ROV is first a remotely operated underwater robot that allows humans to explore the mysterious underwater world without personally entering the water, greatly expanding their ability to explore in the ocean. Secondly, ROV has good wear resistance, pressure resistance and corrosion resistance, which ensures that ROV can work stably and reliably in a harsh underwater environment, and has a long service life. Moreover, the ROV has a high data transmission speed and can transmit video, signals and control signals in real time, which is crucial for underwater operations and detection, ensuring that operators can obtain the required information in time and make corresponding decisions. In addition, ROV can be customized according to different needs to meet the needs of various models and uses, which makes ROV highly flexible and adaptable. Finally, ROV has the outstanding characteristics of safety, economy, high efficiency and large operation depth, which makes it widely used in Marine resources exploration, underwater archaeology, Marine environment monitoring and other fields.

The main body of the study for ROV, the ROV will carry manipulator, ballast, lithium battery, and equipped with two vertical propeller propeller propeller and four vertical propeller propeller, four vertical propeller square distribution outside the frame, two horizontal propeller is located in the end of the frame, on the frame is equipped with two buoyancy materials to provide buoyancy, according to the size weight design of the underwater robot^[4].

The ROV main frame is made of HDPE material. HDPE has high strength and stiffness, and can withstand large pressure and impact force. At the same time, its creep resistance performance is also good, suitable for a variety of complex engineering environment, excellent wear resistance, good corrosion resistance, good processing performance, environmental protection and safety, economic benefits. Each equipment mounted on the frame is fixed to the frame with 6mm loose bolts. The framework of ROV is the main bearing structure, and its strength and stiffness should meet the actual requirements.

3. Design of the frame structure of the underwater robot

3.1. Relevant technical requirements

With the depth of 50m as the design parameter, the water pressure of the underwater robot at 50 meters is: $P = \rho gh = 1000 \times 10 \times 50 = 0.5 \text{MPa}$ After measurement and estimation, the area of the ROV under the underwater pressure is about 0.42m², 0.33m² and 0.265m², respectively. $F = PS$ It can be calculated that the pressure of the ROV on each underwater surface is $2.058 \times 10^5 \text{N}$, $1.617 \times 10^5 \text{N}$ and $1.299 \times 10^5 \text{N}$. The figure 1 below shows a schematic diagram of the underwater robot frame of this design.

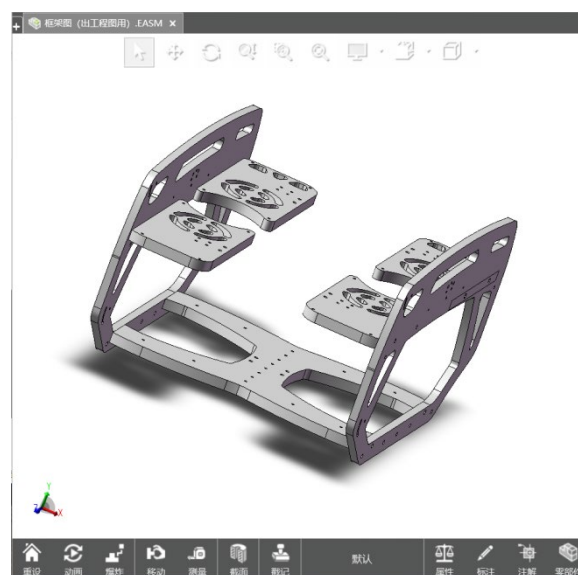


Figure 1: Schematic diagram of the underwater robot framework structure

3.2. ANSYS simulation

The simulation steps and precautions of ANSYS are as follows:

(1) Simulation steps:

Clarify the problem definition: this helps to determine the required boundary conditions and initial conditions, which may involve structural mechanics, hydrodynamics, electromagnetism and other fields.

Geometry modeling: Use ANSYS geometry tools or import external geometric models to create models to ensure that the model geometry, dimensions, and boundaries are correct.

Grid division: divide the geometric model into small grid cells for numerical calculation. The grid should be meticulous enough to ensure accuracy, but computational resources and time constraints should also be considered.

Define the material properties: select the appropriate material model according to the properties and the actual situation of the material, and define the physical characteristics of the material, such as elastic modulus, Poisson's ratio, heat conduction coefficient, etc.

Loading and boundary conditions: define loading conditions and boundary conditions, such as force, temperature, electric field, etc., to simulate the external effects and constraints in practical problems.

Solution settings: Set the solver options and simulation parameters, including selecting the appropriate numerical method, convergence criteria, and number of iterations^[5].

Solving the equations: Use ANSYS's solver to solve the defined problem to better understand and present the simulation results.

(2) Notes: Naming and storage:

The file shall be named in plain English and the location shall be in plain English folder. The name of the working directory should also be in English, and the location of the file should not be too deep in the folder hierarchy, so as not to affect the read and write speed.

Unit type selection: select the appropriate unit type according to the characteristics and requirements of the model^[6]. For example, SOLID236 is the cell type of 20 nodes with intermediate nodes, and SOLID237 is the cell type of 10 nodes without intermediate nodes. In magnetic field calculations, special attention is paid to whether the cell type supports the vortex effect.

Model simplification: If the model is too complex, the appropriate simplification can be considered. For the magnetic field, it can be filled and simplified into a relatively regular shape, and the unnecessary chamfer can be treated as a right Angle or sharp Angle, which has little impact on the accuracy of the results.

The above are only the general steps and precautions of ANSYS simulation, and the specific operation may vary according to the different problems^[7]. Therefore, in the practice process, it also needs to be modified according to the specific environment and requirements of the experiment.

3.2.1 Grid division

First, build a simulation model of the underwater robot needed for the experiment in Solidworks, and save it, and open the established underwater robot model in ANSYS to make sure that you select the correct model file.

Next, click on the grid option. This step is designed to enter the grid setup interface, where various parameters and options related to grid division are visible, setting the data consistent with the experimental content^[8].

Finally, click to divide the grid. This step is to perform mesh hes, which ANSYS automatically based on the previously set parameters and options.

After completing these steps, you can grid them successfully in ANSYS. However, it should be noted that the accuracy and effect of meshing are affected by a variety of factors, such as the complexity of the model, the size and shape of the grid. Therefore, some adjustment and optimization according to the actual situation to achieve the best results.

In this paper, the grid is divided into 186,023 nodes and 42,834 cells. A schematic of the grid

division results is shown in Figure 2.



Figure 2: The ROV grid division diagram

3.2.2 Load and boundary conditions

The reason why underwater robots use HDPE (high-density polyethylene) materials is mainly based on the match between the excellent characteristics of HDPE materials and the needs of underwater robots.

First, the HDPE material has excellent physical properties. Its hardness, tensile strength, and creep are superior to other polyethylene materials, allowing it to perform well under the pressures and challenges of complex underwater environments. In addition, HDPE has good wear resistance, which helps to ensure that the underwater robot can maintain structural integrity and stability during long operation.

Secondly, the HDPE material has an excellent chemical stability. At room temperature, it is insoluble in any organic solvent, and it is resistant to corrosion by acids, bases, and various salts. This characteristic allows HDPE materials to remain stable in underwater environments for long periods of time, free from seawater or other chemicals, thus ensuring the long life and reliability of the underwater robot.

Moreover, HDPE materials have good processing properties. It can be processed through a variety of processes, making the manufacturing process of underwater robots more flexible and efficient. In addition, HDPE materials are also highly plastic, which can be customized and optimized according to the specific needs of the underwater robot to achieve more accurate structural design and functional implementation.

In addition, HDPE materials also have the advantages of waterproof, steam and electrical insulation, which is particularly important for underwater robots^[9]. Steam resistance helps protect the internal structure and electronics from wet environments, and electrical insulation ensures that the robot can operate safely and reliably during tasks.

To sum up, underwater robot use HDPE material because HDPE has excellent physical properties, chemical stability, processing performance, waterproof steam and electric insulation, which can meet the work needs of underwater robot in complex environment and ensure the long life, high reliability and safety of the robot. Therefore, this paper will adopt HDPE as the main material of the underwater robot framework.

The HDPE materials have a high density, usually between the 0.941~0.965g/cm³. This makes it much more robust and durable than other low-density polyethylene materials. From the appearance, the HDPE material presents a milky white or slightly light blue, with a smooth, smooth surface, with a certain gloss. This appearance feature is not only beautiful, but also easy to process and clean. In terms of the mechanical properties, the HDPE material shows an excellent performance. It has high strength and stiffness, and its tensile strength, bending strength and compression strength are all high. At the same time, HDPE material also has good wear resistance, impact resistance and fatigue resistance, and can maintain good mechanical properties for a long time. Thermal properties are also a prominent feature of HDPE materials. The tensile strength ranges from 20 to 40 Mpa, the yield strength is 20 to 22

Mpa, and the Poisson ratio is 0.38. After practical calculation, the actual mass of the underwater robot is 11.15kg, and the maximum shape variable allowed by the support frame is 2mm. The underwater robot is subjected to the seawater pressure in the sea, and the force of each side of the frame is $F = PS$. Assuming that the pressure is evenly distributed on the previously divided unit, the force of each side of the frame structure is shown in Figure 3.

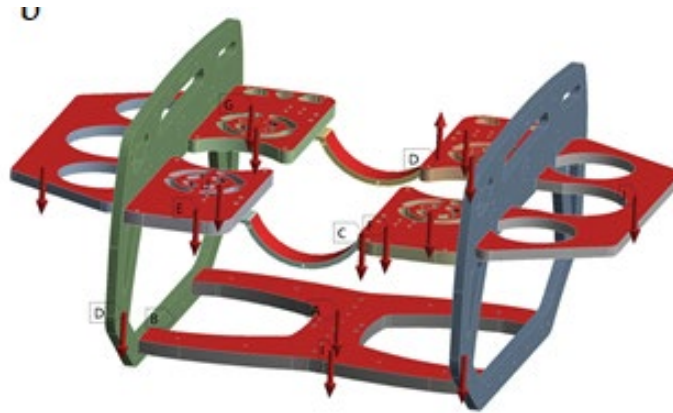


Figure 3: Force Analysis Fig

Because the overall size of the robot is much smaller than the depth, we ignore the error and idealized it. Assuming that the upper and lower surfaces of the robot have equal pressure, the distance from the geometric center point of the robot to the sea surface is taken as the reference depth for the calculation.

3.2.3 ANSYS Workbench for the solution

ANSYS solution is an important link in the ANSYS simulation process, which involves the numerical calculation of the established and divided grid model to solve the corresponding physical field problem. The following is a typical ANSYS solution steps:

Define the analysis options and the solution control: set the analysis types (such as static analysis, dynamic analysis, etc.) and the solution control parameters before starting the solution. These parameters will guide the solver in how to perform the calculations.

Define the load and load step options: according to the actual situation of the problem, define the load applied on the model, such as force, pressure, temperature, etc. At the same time, it is also necessary to set the load step, that is, the load changes over time or other parameters.

Execution solution: After defining the analysis options, solution control, load, and load steps, you can start executing the solution. The solver of ANSYS will numerically calculate the model according to the set parameters and conditions to solve the corresponding physical field distribution.

In the solution process, the following points:

Unit consistency: always ensure that the system of units used is consistent and avoid calculation errors caused by unit inconsistency.

Grid quality inspection: before solving, must check the grid quality. The degree of refinement and the quality of the mesh can greatly influence the accuracy of the solution results.

Convergence judgment: in the process of solving the solution, we need to pay close attention to the convergence of the solution. If the solution does not converge, it may need to adjust the solution parameters or repartition the mesh^[10].

Results verification: After the solution is completed, the results need to be verified. This can be achieved by comparison with theoretical solutions, experimental results or other software calculations.

ANSYS Workbench Studies used Solidworks software for 3 D model building, saved in txt format after modeling, and imported into ANSYS Workbench for pretreatment preparation. In the static structure module of ANSYS Workbench, first ensure the correctness of reasonable selection of boundary conditions and parameters, and then click select select to solve the data. Finally, the results were observed and analyzed by the ANSYS Workbench software. The solution speed is mainly determined by the central processing unit of the computer.

Post-processing includes not only the analysis of the simulation analysis results, but also the optimization of the product design based on the results analysis. With finite element post-processing, critical information about structural behavior, performance and direction of optimization can be obtained to guide further design optimization efforts.

4. Interpretation of result

ANSYS Workbench The software can intuitively present the simulation results, and can observe the overall stress distribution to judge the specific position of the force situation. Based on this information, appropriate measures can be taken to target the vulnerable parts to improve the stability of the overall structure and the quality of the profiles.

4.1 Strength analysis

First, do 3 D model building using Solidworks software, save in txt format after modeling completion, then open ANSYS Workbench, click on the second part to change the engineering data, and import the model into the geometry for pretreatment preparation. In terms of force setting, fixed constraints are applied at both ends of the model to simulate the real situation^[11]. At the same time, according to the pressure corresponding to the working depth, according to the German Lloyd code requirements, the safety factor is 2.

4.2 Analysis of the force of the frame structure

Our established underwater robot model was simulated by using the statics module of ANSYS software^[12]. Under the static load, the framework has different deformation and stress concentration at different locations as expected, and the equal effect force and total deformation are shown in Figure 4, Figure 5 and Figure 6.

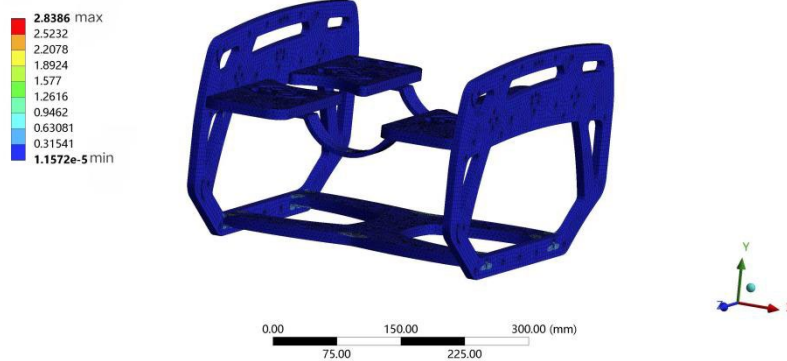


Figure 4: Equal effect

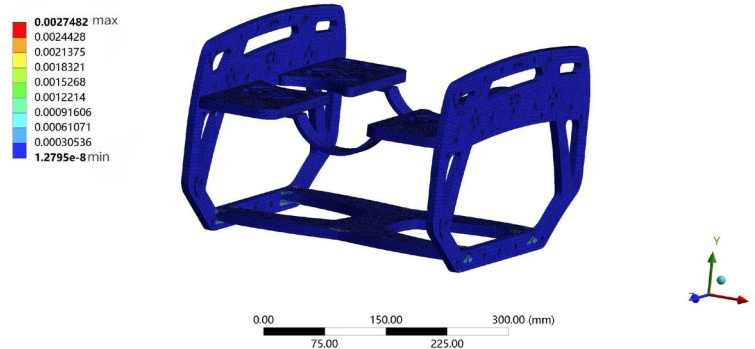


Figure 5: Equivalent elastic strain diagram

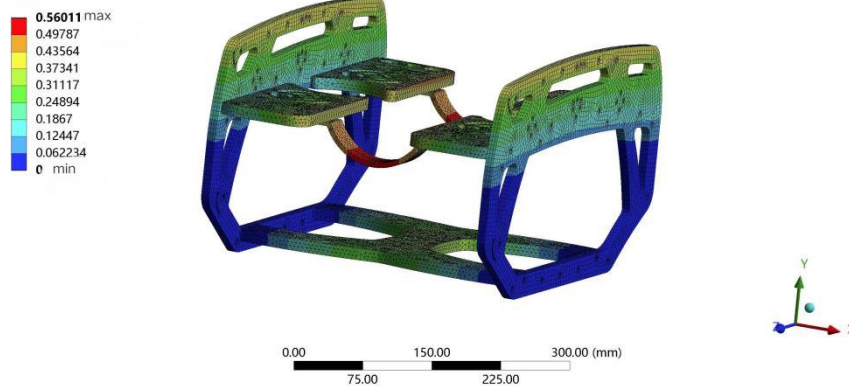


Figure 6: Total deformation diagram

As shown in FIG. 4, it can be seen that the maximum equal effect force of the designed frame is 2.84 Mpa, which is less than the yield strength of 20-22 Mpa of HPDE, so the yield strength of the frame meets the design requirements; and the maximum shape variable of the frame is 0.56mm, so the deformation can be less than the assumed 2mm. Therefore, the framework meets the strength requirements.

5. Conclusion

In this paper, the frame form and basic parameters of the underwater robot are determined according to the actual environment and working principles. First, Solidworks is used for the shape design, and then ANSYS is used to analyze the materials and working parameters to analyze the strength and force analysis of the designed frame structure, and the following conclusions are obtained:

- 1) The theme material of the underwater frame is HDPE, which not only meets the strength requirements, but also has light quality, but also has the advantages of corrosion resistance and low cost;
- 2) Through ANSYS finite element analysis, we determine that the deformation and stability are within our controllable range, which provide the exact data for the subsequent actual production.

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