Development of underwater vehicle’s application in offshore oil and study on the key problems of anti-disturbance control

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Abstract. Underwater Vehicles are promising in offshore oil and gas development, but there are some problems. The beginning of the essay introduces the concept and classification of underwater vehicles. Then the application of underwater vehicle in offshore oil and gas is recommended. This paper briefly introduces the development status of underwater vehicle and the disadvantages of its application in offshore oil and gas engineering. The underwater vehicle needs to carry out fine detection and operation in oil and gas operation. In view of this requirement, the advantages and feasibility of anti-disturbance control in realizing high-precision control of underwater vehicle are analyzed in detail from the angle of motion control.

Keywords: underwater vehicle, offshore oil and gas, refinement, motion control.

1. Introduction

In the vast ocean, there are abundant biological resources, mineral resources and Marine energy. The most economically viable sources of oil and gas are those under the sea. The exploitation of offshore oil and gas resources began to develop rapidly in the 1990s. It will now move from shallow water to nearly a kilometer or several thousand meters deep. In the process of offshore oil and gas development, the use of underwater vehicles can improve the efficiency of work, to reach the depth of water that divers can not reach[1].

2. Concept and classification

Underwater vehicle, also known as unmanned remote-controlled submersible, is a kind of extreme operating vehicle working under the water. Underwater vehicles are suitable for long time and wide range of underwater operations. The main categories are cable-operated remote underwater vehicle (ROV) and cable-free remote underwater vehicle (AUV). The ROV system consists of a surface and an underwater system. Surface equipment includes control console, sonar station, lifting and releasing system, power source and cable, etc. The underwater part of the ROV system is mainly the umbilical cord and the diving body. According to its motion mode, it can be divided into three types: towed type, mobile type (seabed) and floating type (self-propelled). AUVs are often referred to as autonomous underwater vehicles. It is characterized by no cable, more flexible action, its own power energy and intelligent control system. It can rely on its own intelligent control system for decision-making and
control, to complete the work of people assigned mission. AUV represents the development direction of underwater vehicle.

3. Application scenarios
Some western countries, represented by the United States, Germany and France, have made early research and development on underwater vehicle technology, showing an overall leading status. Underwater operation is the core of underwater vehicle system, and oil and gas engineering is one of its underwater operation contents. The applications of underwater vehicles in offshore oil and gas engineering include \[2-3\]: undersea observation, fixed-point sampling, guide drilling work, auxiliary work involved in jacket installation, laying of oil and gas pipelines and inspection and maintenance of offshore petroleum engineering facilities.

4. Disadvantages
The underwater vehicle is an integration of high technology. Although various materials and related technologies of ontology have been basically mature, some key technologies still need to be studied and solved. For example, the problem of underwater communication of cable-free AUV, transmission loss of cable-free AUV, energy quantity of its own power supply module and control problem.

The underwater vehicle moves with six degrees of freedom. It is a nonlinear system with strong coupling, and the direction and velocity of local water flow change irregularly, so the stiffness of the dynamic positioning control system is difficult to meet the requirements of fixed-point operation. Because the control object is 6 degrees of freedom, cross-coupling, nonlinear and time-varying are very serious, so its control technology is very complex. A lot of underwater vehicle operations and observations are now done on the base. In the process of offshore oil and gas development, it is often required that underwater vehicles (AUVs) can carry out detailed exploration and operation such as depth fixing and fixed point in the complex Marine environment. The underwater vehicle needs to achieve high precision motion control. To solve this problem, the anti-disturbance performance of AUV motion control combined with active disturbance rejection technology (ADRC) is studied in this paper.

5. Application of ADRC
The movement of underwater vehicle has six degrees of freedom\[5-6\], that is, forward and backward, left and right, up and down, as well as roll, trim and turn, as shown in Fig.1. And the motion of each degree of freedom has some effect on the other degrees of freedom. So its motion is strongly coupled and nonlinear. At the same time, a series of conditions such as sea water flow, wave and temperature will change due to the different operating sea area and depth. These disturbances are not easy to determine the exact model and are highly nonlinear. This makes it difficult to control the AUV with strong disturbance and time-varying parameters.

![Figure 1. Body coordinate system.](image-url)
5.1. Active disturbance rejection control technology and its principle

Active disturbance rejection control (ADRC) is a control theory developed in recent years. It is a new control technology for strong interference and uncertain system based on nonlinear PID. It has strong robustness, adaptability and nonlinear processing capability. There have been many successful applications in the field of industrial control.

The basic idea of ADRC is to observe the nonlinear dynamic model and uncertain external disturbance in the system as an extended state. Automatically compensates the internal and external disturbances of the system to make it a linear system. And the dynamic feedback linearization of the dynamic system is realized. Then the nonlinear feedback control rate composed of nonlinear configuration is used to improve the control performance of the closed-loop system [7-8].

![Figure 2. ADRC structure diagram.](image)

The ADRC is mainly composed of three parts [9-12]: tracking differentiator (TD), extended state observer (ESO) and nonlinear state error feedback (NLSEF). Trace the differentiator to arrange the transition process. The abrupt part of the input signal can be smoothed, and the input signal and its differential signal can be quickly tracked. The problem of differential signal extraction in practical engineering is solved. It can also filter the input signal. ESO is used to solve the disturbance observation problem when the model is unknown or partially known. ESO is not only able to observe the state of the system, it also designs extended state quantities to track the unknown parts of the model and the influence of unknown disturbances. And then you give the controls to compensate for these disturbances. The nonlinear error feedback control law gives the control strategy of the controlled object and improves the feedback efficiency significantly.

5.2. Design of auto disturbance rejection controller

Since ADRC is adaptive to the uncertainty of the system, ADRC is less dependent on the mathematical model of the system. You can refer to the mathematical model of the system, but you don't completely rely on the mathematical model. By combining ADRC with AUV, the prediction and efficient suppression of external disturbance can be realized autonomously, and the underwater motion control performance of AUV can be improved.

The ADRC designed by MATLAB and Simulink is modular, which can be copied and applied in multiple scenarios. Due to the flexibility and modularization of the controller design, as shown in Fig.3, the mathematical model can be input into the transfer function module to achieve a variety of motion control, such as trajectory tracking, depth fixing, attitude control and so on, under the condition of modifying the AUV model and adjusting some parameters.
5.3. Tracking differentiator effect test
There are many kinds of noise interference in the Marine environment, which makes it difficult for the AUV control system to obtain input signals. Through the simulation test of ADRC tracking differentiator, it is verified that ADRC can obtain and track signals well, which is convenient for further control. As shown in Fig.4, the sinusoidal wave is input and white noise interference is introduced to filter and track through the tracking differentiator.

The sinusoidal input signal $U$ after white noise is introduced is shown in Fig.5.

After the tracking differentiator filtering and tracking, the noiseless input signal $U$ and the differential signal of the input signal $U$ are respectively $U_1$ and $U_2$, as shown in Fig.6. It can be seen that the tracking differentiator has a good filtering and tracking effect.
6. Conclusions
This paper is aimed at the application of underwater vehicle in offshore oil and gas development. Based on the concept and classification of underwater vehicle, the application scenarios of underwater vehicle in offshore oil and gas are briefly introduced. The development status of underwater vehicle technology in China and the bottleneck problems in its application in offshore oil and gas engineering are analyzed. Aiming at the requirements of fine detection and operation of underwater vehicle in offshore oil and gas development, the advantages and feasibility of anti-disturbance control in realizing high-precision control of underwater vehicle are analyzed in detail from the Angle of motion control of underwater vehicle.

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