Technical Research on Engineering Ships Based on Exploration Geological Conditions

Chengzhi Li*
School of Wuhan University of Technology, Wuhan, China

*Corresponding author email: 285804@whut.edu.cn

Abstract. As the main ship type for offshore oil and gas field exploration, the comprehensive geological survey ship has multiple functions such as drilling and sampling, marine hydrological survey, and seabed topography and geomorphology survey. The paper briefly introduces the main technical features, general layout features, ship performance and ship positioning system design of a comprehensive geological survey ship. To improve comfort, the ship optimized the layout of the superstructure. At the same time, the positioning and operation of ships at sea are affected by the disturbance force of the marine environment, and the mathematical model of the dynamic positioning system controller is established. The system uses an active disturbance rejection controller to observe the ship's motion status and the total disturbance of the power system in real time, and uses nonlinear feedback to compensate according to the system disturbance.

Keywords: Geological prospecting, engineering ships, offshore positioning operations, marine environment, mathematical models.

1. Introduction

The development of offshore oil and gas fields is divided into three stages: exploration (searching for oil and gas fields), development and production, among which exploration is the primary task. In the exploration stage, we must first find the geology and structures that are conducive to oil and gas storage, and then find industrial oil and gas reservoirs from these geology and structures, including finding out the size of the oil and gas field, determining the oil and gas reserves, and clarifying the oil and gas reservoirs. Nature, etc., to prepare for oil and gas field development. The survey ship mainly serves the exploration stage, and provides the submarine geological structure and engineering design basic parameters for the development stage [1]. There are two main methods for offshore oil and gas field exploration: engineering geological survey and engineering geophysical survey. Among them: engineering geological survey method mainly uses engineering geological drilling and other means to obtain seabed soil samples and conduct seabed geological survey research; engineering geophysical survey method is based on the physical properties of underground rocks Use various exploration instruments to measure and understand the underground structure. In order for the ship to maintain its position in a certain position or drive in the target direction in heavy winds and waves, the ship must take certain measures to effectively offset the reverse force and moment generated by external interference forces such as wind and waves. The ship dynamic positioning system can control the
current position and navigation direction of the ship in real time, and it is the most extensive and effective positioning system in the process of ocean navigation.

2. Ship system function and structure

2.1. The function of the dynamic positioning system

The system can ensure the maximum safe navigation of the ship. In the actual navigation process, the dynamic positioning system can complete four controls: fixed-point control, track control, tracking control and tracking control. Fixed-point control mainly refers to the control of the ship's horizontal, vertical and swaying three degrees of freedom [2]. The core part is the controller. The controller can determine the position of the ship by measuring the data of the system and then computing; the track control refers to the Under normal working conditions, the entire ship can sail according to the predetermined trajectory to ensure the accuracy of navigation; the content completed by the line tracking control is basically the same as the track control, and the difference between the two is that the line tracking control requires the heading of the ship In the course of sailing, it should also be consistent with the predetermined trajectory and have a wider range; the tracking control function is to automatically track the target, determine the distance to the target ship through the detection system, and control the propeller to operate and control in real time according to the feedback information.

2.2. The structure of the dynamic positioning system

Functionally speaking, the main structure of the dynamic positioning system is the measurement system, the power system, and the controller, as shown in Figure 1. These three subsystems can form a complete position servo control system during the ship positioning process. The servo control system has the characteristics of multi-variable, nonlinear, time-varying and large lag.

![Figure 1. Overall block diagram of the dynamic positioning system](image)

Each module of the ship dynamic positioning system has a clear division of labour. First, the measurement system collects information, monitors the deviation of the ship's position from the predetermined position in real time, and also considers the impact of the external environment on the ship's navigation during the collection process, and feeds the collected information to the controller. The controller is the brain of the entire system. It calculates the thrust required by the ship to reach the target position through the collected data, and distributes the ship's power through the thrusters, so that each thruster distributes the thrust according to the instructions to ensure that the ship is on the ocean as required. The track is sailing normally. In the marine dynamic positioning system, the controller receives commands, which is the initiating part of the operation of the entire system. When the controller receives the commands, it will send the commands to other units of the system, and other units of the system are responsible for executing specific commands. Each module is connected through the controller, and the controller issues instructions to ensure the effective operation of the entire system and accomplish the set goals.
3. Mathematical model of ship motion control and seabed geological exploration technology

3.1. Mathematical model of ship motion control

First establish the ship's motion coordinate system, including the ship's coordinate system and the geodetic coordinate system, as shown in Figure 2. The ship-on-ship coordinate system is fixed on the ship and represents the movement with the centre of mass of the ship as the origin; the ground coordinate system is fixed on the earth and represents the position change and speed change of the ship. Ship-borne signal acquisition equipment, such as speed sensors, angle meters, etc., collect signals with ship-borne coordinate system signals and need to be converted to the ground coordinate system [3]. In the above-mentioned ship motion coordinate system, the ship motion model is established as follows:

\[
\begin{bmatrix}
F_x \\
F_T \\
F_z
\end{bmatrix} = J_{xyz} \left[ \theta \left( \frac{\pi}{2} - \theta \right) \right] \begin{bmatrix}
\dot{u} \\
\dot{v} \\
\dot{r}
\end{bmatrix} m
\]

(1)

In the formula: \( J_{xyz} \) is the moment of inertia of the ship; \( [\dot{u}, \dot{v}, \dot{r}]^T \) is the acceleration component of the ship, and the conversion relationship between the ship coordinate system and the ground coordinate system is:

\[ k = \eta(\alpha)V_c \]

(2)

Where: \( \eta \) is the conversion angle of the two coordinate systems; \( V_c \) is the speed of relative motion. The adaptive fuzzy controller uses an adaptive learning algorithm to adjust the parameters of the fuzzy logic control system, takes the error between the theoretical output and the actual signal as a new input signal, and continuously iteratively optimizes until the output signal meets the design requirements [4]. The input signal of the fuzzy controller is the nonlinear model of the dynamic positioning system, as follows:
\[ \mu = R(\psi)v \]
\[ M\dot{v} = -Dv + \tau + w \]  
(3)
\[ \tau = 0.3 \times \frac{\delta v}{dt} \]

In the formula: \( w \) is the steady disturbance; \( v \) is the ship moving speed; \( R(\psi) \) is the rudder angle change function; \( \tau \) is the acceleration. The error variables of fuzzy control are:

\[ \delta = \eta - \eta_0 \]  
(4)

The time derivative of the error variable is:

\[ \frac{d\delta}{dt} = \dot{\eta} - \dot{\eta}_0 = R(\psi)v - \frac{d\eta_0}{dt} \]  
(5)

The function expression of the adaptive fuzzy controller can be obtained by the force product method:

\[ f(t) = \frac{\sum_i^n \sum_j^n \left( \left( R(t)v - \eta_0 \right) \right)}{\sum_i^n \sum_j^n \eta(t)} \]  
(6)

3.2. Requirements of marine engineering geological survey technology for ships

When conducting engineering surveys in deep water areas, the requirements for ships are much higher than those in shallow water areas. The sea conditions in deep waters are much worse than those in shallow waters. Ships must have strong wind and wave resistance, and ships must have larger tonnage. In addition, various deep-water survey equipment also put forward corresponding requirements for ships, including deep-water survey ships that need to be equipped with a high-precision dynamic positioning system, multiple sets of multi-purpose 10,000-meter deep-water winch systems, and sufficient geological sampling equipment, In-situ testing equipment and submarine deep submersible combined detection system, and other equipment space, sufficient instrument room and operating deck area, deep water equipment is mostly large equipment, need to install "m" frame and supporting winches, etc.

3.2.1. Power and propeller equipment. All the mechanical equipment equipped on the Deepwater engineering geological survey ship are high-quality marine equipment, and standardized as much as possible to facilitate maintenance and reduce spare parts inventory. The layout and operation of the system and equipment are safe, easy to approach and convenient for inspection and maintenance. All systems and components work under environmental conditions that meet the requirements of relevant specifications and rules. In order to meet the work of all equipment and systems, the main diesel generator set is equipped to meet the effective classification society regulations, and the certificate is provided in accordance with the requirements of the classification society regulations and the requirements of the marine class symbol. The installation of the main power station in the ship needs to meet the needs of ship drilling operations, dynamic positioning, and various work and life needs in the ship [5]. The main engine is started with compressed air and the fuel is marine diesel with sulfur content. The cooling method of the main engine generator is air fresh water, the inside of the generator is a closed air-cooled circuit with water cooling, and the generator shaft is equipped with a forced ventilation fan.
3.2.2. Dynamic positioning system. The dynamic positioning system of the marine engineering geological survey ship can be configured according to the requirements of the classification society. The dynamic positioning system is mainly composed of power and thruster systems, measurement systems and automated control systems. The power and thruster system are responsible for providing sufficient power and effective manoeuvrability for the ship. The power system consists of the main generator and advanced power station management equipment [6]. The propeller provides the power to resist external forces and improve manoeuvrability. The manoeuvrability of the dynamic positioning vessel is very superior, and it can turn around in place.

Under normal sea conditions, even if an electric propulsion system and a thruster fail at the same time, the dynamic positioning function and ship manoeuvrability can be maintained, that is, there is a certain degree of redundancy. The dynamic positioning system is operated by a joint joystick. The joint joystick system consists of an embedded operation panel, a controller unit, a two-wing portable operation panel, and a two-wing portable operation panel junction box. The available operation modes are joint control mode, automatic heading mode, autopilot mode, and geophysical track mode. All the modes and functions of the dynamic positioning system software should meet the requirements of the ship's main operational functions, such as engineering geological drilling sampling, high-resolution seismic survey, deep-water shallow sectioning, and seabed sampling [7].

3.2.3. Seakeeping of the ship. The deep-water marine engineering geological survey ship has a variety of operating functions and is equipped with a variety of professional equipment. The configuration of these functions and equipment has high requirements for the seakeeping performance of the hull. If the seakeeping performance of the hull is not good at zero speed, it will directly affect the operation safety and efficiency of these equipment. Good seakeeping ensures the correct selection of large equipment such as drilling rig systems and helicopter platforms and the safety of operations, and it also provides an effective basis for structural design.

4. Simulation Research
In order to verify the performance, the simulation experiment of the ship dynamic positioning system controller was carried out through MATLAB 7.0. In the simulation experiment, the ship length is 175m, the ship width is 25m, and the displacement is 6000t. In this simulated ocean environment, it is necessary to provide some external disturbance factors, waves and ocean currents. It can be defined that the significant wave height of the wave is 5m, the peak frequency is 0.8rad/s, the wave direction is 120°, and the flow velocity is 0.2m/s. The original position and the given position of the target ship need to be selected, which are marked as (0m, 0m) and (20m, 20m) respectively. The position response curve can be obtained through simulation as shown in Figure 3. From the curve, it can be found that the target ship can quickly reach the given position with little overshoot. Under the action of waves and currents, the position remains within 3m of the given position. It can be seen from the speed curve that the speed after adopting the auto disturbance rejection controller is relatively stable, with small fluctuations up and down, which can play an anti-interference effect.
5. Conclusions
Underwater detection technology is an important technical support in the fields of marine resource exploration and seabed geological survey. The technology of the Deepwater engineering geological survey ship involves ship technology, offshore petroleum geophysical prospecting technology, and drilling technology and equipment. It is a comprehensive technology integration and is a major equipment for offshore oil engineering. Through the discussion of the deep-water engineering survey ship, the advantages of this equipment and technology are still abroad, and there is still a certain gap in the level of our country, especially in ship design and advanced equipment matching.

References
[1] Caineng, Z. O. U., Zhi, Y. A. N. G., Dongbo, H. E., Yunsheng, W., Jian, L., Ailin, J., & Shen, Y. Theory, technology and prospects of conventional and unconventional natural gas. Petroleum Exploration and Development, 45(4) (2018) 604-618.
[2] Coakley, B., Brumley, K., Lebedeva-Ivanova, N., & Mosher, D. Exploring the geology of the central Arctic Ocean; understanding the basin features in place and time. Journal of the Geological Society, 173(6) (2016) 967-987.
[3] Gehrmann, R. A. S., North, L. J., Graber, S., Szitkar, F., Petersen, S., Minshull, T. A., & Murton, B. J. Marine mineral exploration with controlled source electromagnetics at the TAG Hydrothermal Field, 26° N Mid-Atlantic Ridge. Geophysical Research Letters, 46(11) (2019) 5808-5816.
[4] Morelos-Rodriguez, L. Brief history of geological and mining exploration in nineteenth century Mexico. Geological Society, London, Special Publications, 442(1) (2017) 303-313.
[5] Pizzolato, L., Howell, S. E., Dawson, J., Laliberté, F., & Copland, L. The influence of declining sea ice on shipping activity in the Canadian Arctic. Geophysical Research Letters, 43(23) (2016) 12-146.
[6] Brennan, M. L., Cantelas, F., Elliott, K., Delgado, J. P., Bell, K. L., Coleman, D., & Ballard, R. D. Telepresence-Enabled Maritime Archaeological Exploration in the Deep. Journal of Maritime Archaeology, 13(2) (2018) 97-121.
[7] Huihui, Z. H. U., Dejun, L. I. U., Shuo, F. E. N. G., Qi, P., & Jingfu, Y. Magnetic dipole reconstruction geometry modeling for underground ferromagnetic pipe magnetic abnormal detection. Computer Measurement & Control, 25(3) (2017) 201-204.