

Dynamic positioning test for removable of ocean observation platform

Ye Li, Li An^{*}, Yanqing Jiang, Jiayu He, Jian Cao, Hongda Guo

Science and Technology on Underwater Vehicles Laboratory, Harbin Engineering University, 150001, China



ARTICLE INFO

Keywords:

Dynamic positioning
Weather optimal heading
Improved S plane control
Fixed-output time control
Grouping thrust allocation

ABSTRACT

A removable ocean observation platform for horizontal plane dynamic positioning test under the disturbance of ocean currents was completed successfully in the deep-water pool at Harbin Engineering University. The control system for the surge, sway, and yaw is designed according to the characteristics of the observation platform. Sigmoid (S) plane control is used to resist ocean current disturbances by the improved adaptive term. The target heading is chosen based on the theory of weather optimal positioning control (WOPC) such that when the platform maintains the target heading, the energy consumption of the propulsion system is minimal. A fixed-output time control approach is proposed for the platform heading control to avoid the effect of thruster dead zone. Then, a grouping strategy based on the analysis of the main disturbance is introduced for thrust allocation. The effectiveness of the proposed control scheme and thrust allocation method is illustrated by pool trials. Several effective suggestions are proposed for the design of dynamic positioning systems and the positioning control of the removable ocean observation platform.

1. Introduction

Since the 1990s, ocean observing systems (OOS) have been established worldwide (Wallinga et al., 2003). Ocean observation has played an essential role in ocean exploration. Data collected by observation platforms help to answer a range of fundamental and applied research questions (Liu et al., 2016). These include temperature, salinity, and density at different depths measured by conductivity-temperature-depth (CTD) instruments, and the velocity of water currents throughout the acoustics Doppler current profile (ADCP). Underwater observation devices are generally divided into two categories: fixed and removable (Tzeng et al., 2010). Canada has deployed a fixed platform, the VENUS Instrument Platform (VIP), continuously from 2006 to 2016 in the Saanich Inlet to obtain data regarding the ocean state (Abeyisirigunawardena et al., 2016). The Shenyang Institute of Automation Chinese Academy of Sciences presented a removable platform for ocean observation, which was designed as a jellyfish shape. It is particularly suitable for fixed points or Small area and underwater slit and gully areas of ocean observation (Meng et al., 2016).

The ocean observation platform of this paper is also a type of removable observation platform. The observation platform is equipped with a heave device and propulsion systems, so it can complete depth location and dynamic positioning. The platform essentially works as follows: it remains at a fixed point in the sea or on the bottom of the sea

for ocean observation. It also can transform from one fixed point to another. Some characteristics of the platform include low cost, high environmental adaptability, independent motive power, long operational time, low active noise, and ability of covert observation. Therefore, it can be applied to an autonomous wider range and long-term underwater observation.

The platform collects ocean data at a fixed point and will suffer the disturbances of current. To provide a safe work environment, the dynamic positioning of the observation platform in the current must be studied.

Currently, the research of dynamic positioning focuses on deep-sea work ships, floating production systems, and remotely operated vehicles (ROVs). Early dynamic positioning systems were built using PID controllers; then, notch filters in cascade with low pass filters were used with the controllers to reduce the thruster trembling caused by the wave-induced motion components. Improved performance was achieved by exploiting more advanced control techniques based on optimal control and Kalman filter theory (Balchen et al., 1976). Recently, an artificial intelligence method was introduced into the dynamic positioning system. Considering unknown time-varying disturbances, Du et al. (2013) presented a robust adaptive neural controller for the dynamic positioning system, where unknown ship model dynamics and time-varying disturbances are compensated for by adaptive radial basis function (RBF) neural networks. Simulation results demonstrate the effectiveness and

^{*} Corresponding author.

E-mail address: anli0315@hrbeu.edu.cn (L. An).

robustness of the proposed control scheme.

This control method is not suitable for the ocean observation platform's dynamic positioning system because there is a difference between the working environment and working mode for the ocean observation platform and the dynamic positioning system mentioned. The observation platform has the following features:

- (1) As the actual observation platform is submerged in a homogeneous fluid 10 m from the surface, only the current disturbances should be considered for the observation platform.
- (2) The platform only needs to realize a fixed position and a certain heading angle because of the requirement of the operation mode.

Accordingly, some practical engineering problems are considered, including the energy consumption, dead zone of the thruster output, and fast thrust allocation strategy. The idea of weather optimal heading is introduced to the control system to minimize the energy consumption. Fossen and Strand (2001) presented the concept of weather optimal positioning control for marine operation systems. Moreover, he proposed a method to solve the optimal heading. The controlled ship moves in a circle with a fixed radius by pointing the bow of the ship toward the origin of the circle. The optimal heading of a dynamic-positioning ship can be obtained when the yaw moment is zero. However, the implementation of this motion process is complex and time-consuming. The dead zone means that the thruster has no output at low speeds. The observation platform is a revolving body with small inertia. Owing to the unknown dead zone of the thruster, there is a long period of buffeting in the heading control. However, many control strategies ignore the dead zone. Xia et al. (2015) presented a feed-forward fuzzy compensator that is designed to eliminate the effects of the dead-zones. The simulation results prove its effectiveness; however, the engineering practicability is poor.

In this study, the pool test system is designed for the observation platform. The control system is designed according to the features of the observation platform, which simultaneously considers the current disturbances, weather optimal positioning control, and thruster dead zone. The improved adaptive term of S-plane control is used to resist the current disturbances. The weather optimal positioning control is achieved by setting the current direction as the target heading, and the dead zone problem is solved by fixed-output time control, based on which the dynamic positioning control law is designed. Then, the grouping strategy is introduced to thrust allocation, which increases the system practicality.

2. Problem formulation

2.1. Vehicle modeling

Establish an inertial reference coordinate system $\{I\}$ with the origin defined on Earth and a body-fixed coordinate system $\{B\}$ with the origin chosen to coincide with the observation platform's center of mass, as shown in Fig. 1. The mathematical model of the observation platform in the horizontal plane can be described as follows (Fossen, 2011):

$$\begin{cases} \mathbf{M}\dot{\mathbf{v}} + \mathbf{C}(\mathbf{v})\mathbf{v} + \mathbf{D}(\mathbf{v})\mathbf{v} = \boldsymbol{\tau} \\ \dot{\boldsymbol{\eta}} = \mathbf{R}(\phi)\mathbf{v} \end{cases} \quad (1)$$

$$\boldsymbol{\eta} = [x \quad y \quad \psi]^T, \quad \mathbf{v} = [u \quad v \quad r]^T \quad (2)$$

$$\boldsymbol{\tau} = [\tau_u, \tau_v, \tau_r]^T \quad (3)$$

where, x and y are the position of the observation platform's center of mass in $\{I\}$; ψ denotes the heading angle in $\{I\}$; u , v , and r denote the surge, sway, and yaw velocities expressed in $\{B\}$. The model matrices $\mathbf{M}\mathbf{C}(\mathbf{v})$, and $\mathbf{D}(\mathbf{v})$ denote inertia, Coriolis, and damping, respectively; $\mathbf{R}(\psi)$ denotes the rotation matrix between the two coordinate systems; τ_u ,

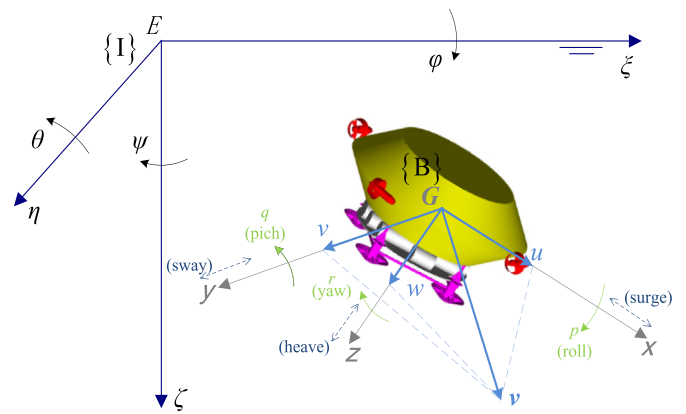


Fig. 1. Coordinate system of observation platform.

τ_v , and τ_r are the surge, sway force, and yaw moment, respectively.

2.2. Problem formulation

According to the characteristics of the observation platform, the following problems should be considered during the dynamic positioning system design:

- a) What control method can perform well in resisting ocean current disturbances in real-time?
- b) How can we choose the target heading angle so that the energy optimization can be achieved?
- c) How can we design the heading controller so that the influence of dead zone can be avoid?

The general control problem of dynamic positioning for the observation platform considered in this study can be formulated as follows. Considering an arbitrary state expressed in $\{I\}$ with desired state $\boldsymbol{\eta}_d = [x_d \quad y_d \quad \psi_d]$.

Define the dynamic positioning error:

$$\boldsymbol{\eta}_e = [x_e \quad y_e \quad \psi_e] = [x - x_d \quad y - y_d \quad \psi - \psi_d]$$

Thus, the control objective of the dynamic positioning of the observation platform is to design control law τ_u , τ_v , and τ_r to ensure the positioning error $\boldsymbol{\eta}_e$ converges to an arbitrarily small neighborhood of zero as $t \rightarrow \infty$.

3. Dynamic positioning control system design

Referring to the definition of weather optimal heading, the target heading can be determined according to the direction of the main disturbance (direction of current disturbance in this study). Then, the improved S-plane control is designed in the positions x and y , and a fixed-output time control based on the idea of time-optimal control is built in the heading ψ . Thus, the structure of the control system for the observation platform is shown in Fig. 2.

3.1. Improved S-plane control design

Liu and Xu (2001) presented S-plane control based on the idea of fuzzy control. Engineering practice shows that the S-plane control has a strong practical aspect. Thus, it is chosen to solve τ_u and τ_v .

The expression of S-plane control is:

$$f = \frac{2}{1.0 + e^{k_1 e + k_2 \dot{e}}} - 1.0 + \Delta f \quad (4)$$

where, e and \dot{e} are the error and its deviation, respectively; and k_1 and k_2

Download English Version:

<https://daneshyari.com/en/article/8063035>

Download Persian Version:

<https://daneshyari.com/article/8063035>

[Daneshyari.com](https://daneshyari.com)