A Novel Speed and Position Control Algorithm using Double Closed Loops to Stabilize Ship Platforms

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***Abstract* — Ships at sea are affected by factors such as waves which will produce a swing phenomenon. By constantly measuring the attitude of the platform and the change in position, a control system is developed to eliminate all interferences and insulate disturbances to stabilize objects on the carrier and maintain dynamic attitude reference accurately. This paper explores controllers of marine platforms to develop an attitude controller using a double closed loop speed position control system and proposes a method of variable parameter PID algorithm to deal with different tracking angles. It then builds a marine structure platform test system and debugs it using single and double closed loop systems respectively. Finally it obtains comparisons with experimental results and discusses further analysis.**

Keywords - Marine platform; Variable parameters PID control; Double closed loop speed position

I. INTRODUCTION

Marine platform is an important device control platform, which continuously measures changes in attitude and position of the platform, eliminates or insulates averse effects on the hull generated by all kinds of disturbances, To ensure that the platform is always in a horizontal position,So as to maintain the stability of the platform frame equipment. Ship stability tracking platform is designed for eliminating the influence of platform stability and target tracking. Stable tracking platform control system is an important part of ship control system[1]. Therefore, the attitude control system of marine platform herein used double closed loop speed position PID control system.Using double closed loop system with speed as the inner ring, position as outer ring to improve stability and anti-jamming capability of the system.

II. SPEED LOOP AND DOUBLE-LOOP POSITION CONTROL LOOP DESIGN

A. Speed Loop Design

In the marine platform attitude control system, speed loop has influenced on system stability and dynamic performance of the marine platform attitude control system, it can insulate the carrier disturbances to reduce the impact on the error angle generated by the movement of the carrier platform, improving system disturbance rejection.

Speed loop is designed to meet the dynamic characteristics required by the position loop , to meet the speed range required by the system and meet the requirements of the torque error on speed loop, not only the open loop gain of speed loop is large enough, but also need to have good speed characteristics and mechanical properties [2]. The main factor affecting the dynamic characteristics of the speed loop is the gain of loop transfer function, the structure with double closed loop can significantly improve the ability of anti disturbance of the system for secondary disturbances, reduce the time constant and the phase lag of the object , so as to improve the dynamic performance of the system, bandwidth and the structure of the transfer function, the design of the speed loop is to determine these parameters to achieve the dynamic characteristics required by the position loop.

B. Position Loop Design

In the marine platform attitude control system, position loop[3] has influenced on the system accuracy. It can insulate the external disturbance on platform to keep the equipment stable in inertial space and improve the accuracy of the system.

Position loop is designed to improve the control accuracy, control the input and output signals and drive executive motor to move in the direction of reducing deviation signal and achieve fast and stable output of the input to follow[4].

Position loop control is a very important part in the control system of marine platform.The design of the position loop should meet the following requirements：

Isolate the effect of external disturbance on the platform,such as carrier shaking and so on,to keep the equipment stable in the inertial space.Position loop bandwidth can not be greater than the speed loop bandwidth.Meet the system requirements of the dynamic performance index,response speed, settling time, accuracy of the system within a reasonable range.

The position speed double closed loop structure is shown in Figure 2, which is an improvement to the traditional PID[5] position speed single loop shown in Figure 1.

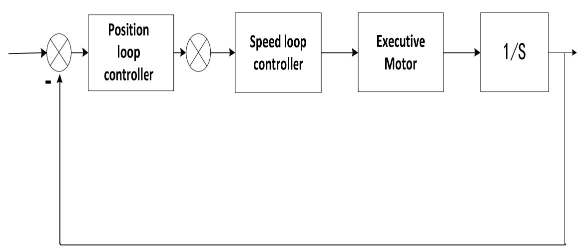

Fig1.Position speed single closed loop

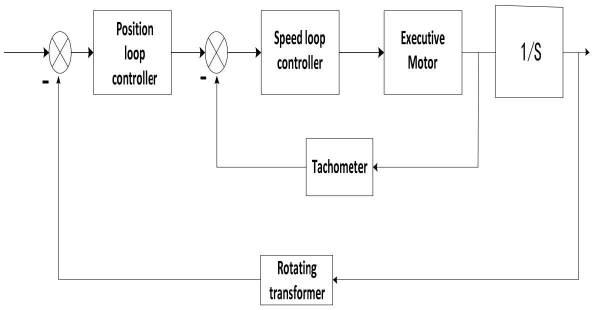

Fig2. Double closed loop speed position control system structure

III. DOUBLE CLOSED LOOP SPEED POSITION PID ALGORITHM SIMULATION

A. The Selection of Speed Position Double Closed Loop PID Control Method

According to the rule of PID control,the ratio link is mainly through the coarse adjustment of the error, to ensure the stability of the system.Integral link and differential link are to shorten the time of the system regulation，speed up the reaction rate and eliminate the static difference.So as to ensure the accuracy and rapidity of the control system[6]

Because the traditional PID control is applied to the practical application, which will come into being nonlinear and time varying uncertainty ,the mathematical model of the system can not be established accurately. Due to the control object has large inertia, strong interference, nonlinearity and other characteristics, the preset parameters can not achieve the expected control effect[7]. The variable parameter PID control algorithm is an improvement of the traditional PID control algorithm[8]. According to the calculation of the size of deviation, the proportional link, integral link and differential link can change the effect intensity in control system, and can have hand in the control link accurately. So this paper chose the method of the speed position double closed loop PID variable parameter control. The fixed angular velocity mode and dynamic mode were designed and simulated.

B. Mathematical Model of Double Closed Loop of Speed Position

In this paper, the choice of the implementation of the motor model is Y132S2-2 ,The mathematical model of DC torque motor can be established according to the following formulas[9], the implementation of the motor transfer function [10,11] was obtained from formula (1) to (5) and the motor parameters according to Table 1 .

TABLE 1. IMPLEMENTATION OF MAJOR MOTOR RATED DATA

Characteristic	Ratings
Continuous Stall voltage Ua (V)	55
Continuous Stall Electric current Ia (A)	7.5
Continuous stall torque Tm(N.m)	150
Maximum load speed n_0(r/min)	27
Rated Rotating speed n_0(r/min)	2900
Rated power factor	0.88
Armature resistance Ra（Ω）	7.7
Moment of inertia of the armature J(kg/m2)	0.87
Armature inductance La(mH)	110

Motor torque coefficient :

$$Cm = \frac{T_m}{I_a} \tag{1}$$

The potential of the motor constant：

$$Ce = \frac{U_a}{\omega} \tag{2}$$

$$Ce = \frac{U_a}{2\pi n_0} \tag{3}$$

Motor time constant：

$$Tm = \frac{R_a J}{C_m C_e} \tag{4}$$

$$Te = \frac{L_a}{R_a} \tag{5}$$

Motor system transfer function:

$$\text{G（S)} = \frac{W(S)}{U(S)} = \frac{1/Ce}{(T_m S+1)(T_e S+1)} = \frac{11.245}{(3.75S+1)(1.42S+1)} \tag{6}$$

C. Simulation of Double Closed Loop of Speed Position

(a) Fixed angular velocity mode

Fixed angle velocity mode used PI controller, and joined the integral separation. when the system’s error was large, without quoting integral action, Only when the deviation was smaller, then the integral action was quoted.Integral separation to ensure that the larger error will not cause the accumulation of points, Avoid causing a large overshoot in the system, to improve the control accuracy of the system[12].Figure 3 showed the fixed angle following mode of double closed loop control simulation model.

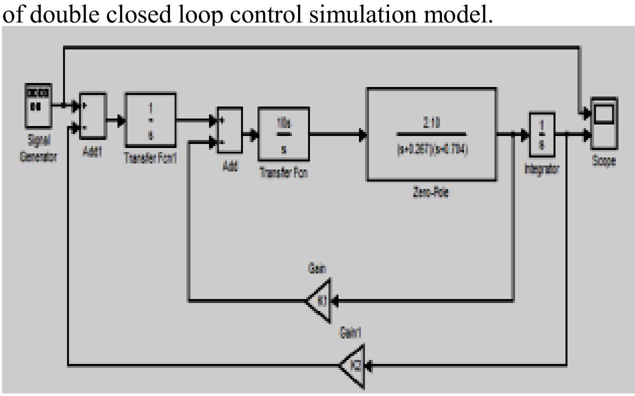

Fig3. fixed angle following mode double-loop control simulation diagram

Using matlab7.0 simulation of double closed loop control algorithm[13].When a step signal was entered, the response curve was obtained as shown in Figure 4.

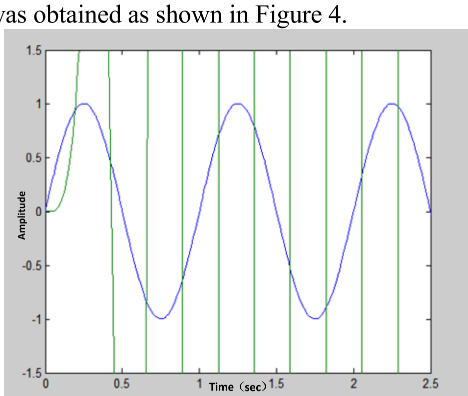

Fig4.Fixed angular velocity mode step response curve.

The trace output curve obtained from the given input signal,which displays the tracking curve oscillation is lager,Tracking performance is general.Due to the sea environment changes from time to time,Fixed angular velocity mode has a dead zone,The change of angle velocity's control accuracy is low.Availability and is not high.

(b)Dynamic Model

The dynamic model system used the PD controller, which did not exist integral separation and dead zone. The PD controller can generate a valid early signal system according to the variations of the input signal advanced reaction. To ensure that the system dynamic performance, reduce recovery swing phenomenon and increase the level of damping system and improve the system stability.

Figure 5 shows the dynamic following model of the double closed loop control.

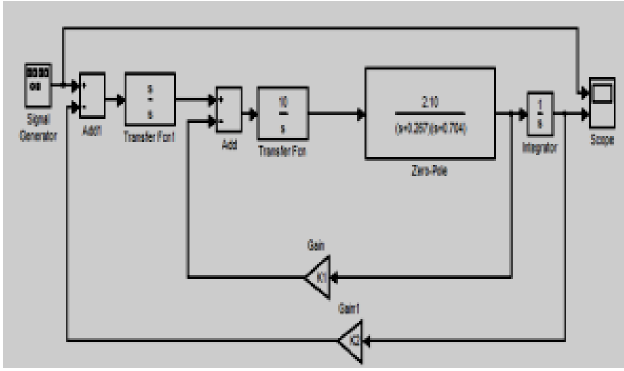

Fig5. Fixed angle follow-up mode double-loop control simulation diagram

Using matlab7.0 simulation of double closed loop control algorithm[14]. When a step signal was entered, the response curve was obtained as shown in Figure 6.

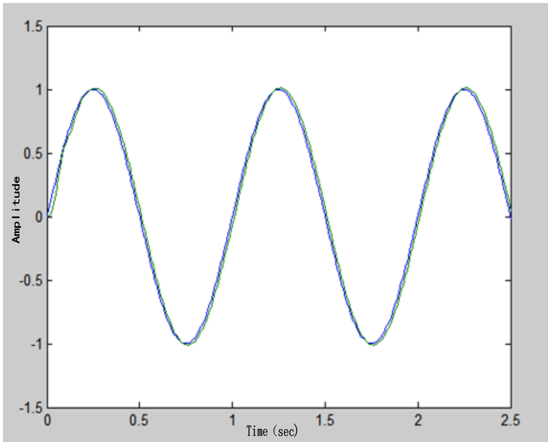

Fig6. Dynamic simulation results follow mode.

The trace output curve obtained from the given input signal ,which can be seen that tracking curve is relatively smoother, tracking performance is superior, which has adaptive, control accuracy is very high. From the simulation results, the performance index of the system meets the system requirements by adopting variable parameters PID dynamic control method with double closed loop.

III. EXPERRIMENTAL ANALYSIS OF TEST RESULTS

System Requires Specifications steps:

(a) Static performance indicators:

Whole system linkage, set a fixed angle on the control terminal of the experimental platform, after sending to the controller, The controller drove the platform to rotate to a specified angle, then observed the angle indicator on the experimental equipment, the difference between the sending angle of the platform control terminal and the angle of the indicator,which is tracking accuracy[15].

(b) Dynamic performance indicators:

Whole System linkage, set the dynamic and continuous rolling mode on the control system of the experimental platform. To observe experimental platform.and set the angle number between + 10 °to -10 °to do continuous rocking angle,The angle error is calculated by reading the actual follow angle value.

A. Single Closed Loop Test And Result Analysis

Test Purpose: Verify if the following angle of a single closed loop and fixed angle are consistent, by comparing the following angle and the fixed angle difference as shown in Figure 7and 8, and using （7）and（8） formulas to calculate the average error of them, judge if the analysis results meet the system requirements.

Mean error value formula:

$$\overline{a_i} = \frac{a_1 + a_2 + \ldots + a_n}{n} \qquad (7)$$

$$\overline{\triangle a} = \frac{\sum_{i=1}^{n} \left| a_i - \overline{a_i} \right|}{n} \qquad (8)$$

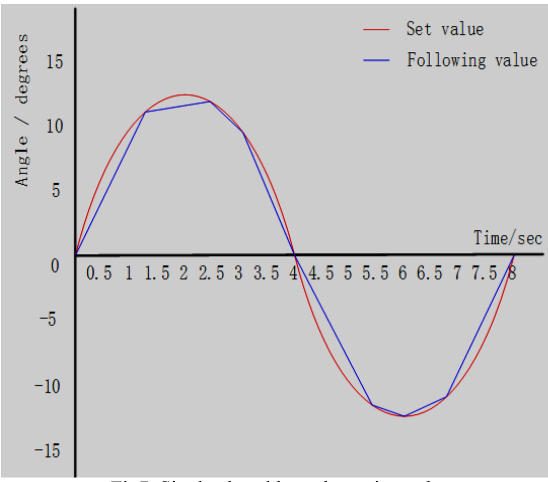

Fig7. Single closed loop dynamic mode

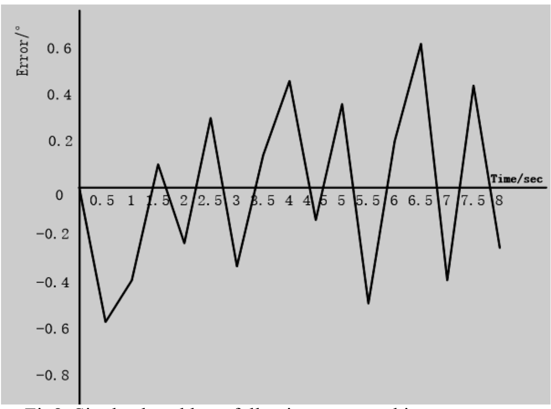

Fig8. Single closed loop following curve tacking error curve

Test Conclusion: Continue same action 20 times, the error values of single closed loop tracking angle and the given angle are obtained.According to the average error value formula ,take the arithmetic mean to obtain tracking accuracy of 0.603° , more than 0.5° ,it does not meet the requirements of the system standard.

B. Double Closed Loop Speed Position Test And Results

Test Purpose: Verify if the following angle of a single closed loop and fixed angle are consistent, or the error of the system requirements is ± 0.5 . By comparing the following angle and the fixed angle difference as shown in Figure 9and10 and calculating the tracking accuracy with （7）and（8）formulas, judge if the results meet the standards of the system requirements.

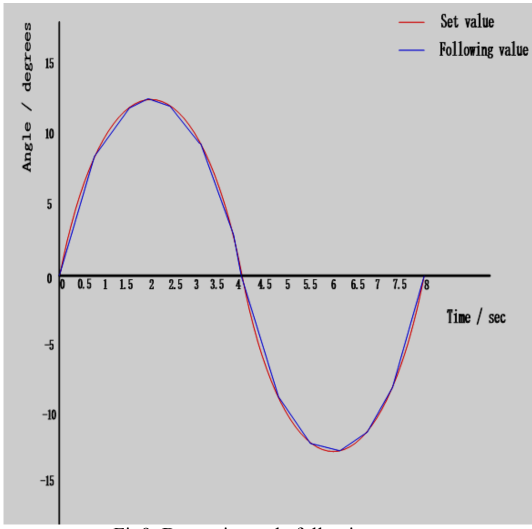

Fig9. Dynamic mode following curve

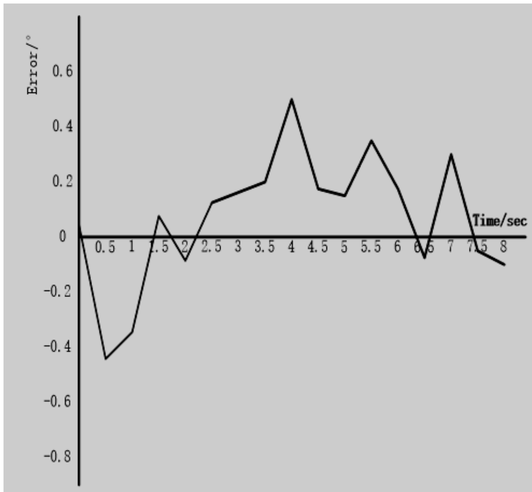

Fig10. Double-loop tracking error curve

Test Conclusion: Continue same action 20 times, The error values of the double closed loop tracking angle and the given angle are obtained.According to the average error value formula, take the arithmetic mean to obtain tracking accuracy of 0.405 °, less than 0.5 °, The results meet the system requirements of the standard.

Through experimental observation, compared with the single closed closed loop controller experimental platform, double closed loop speed position controller experimental platform runs more continuously and smoothly, without significant recovery and pendulum oscillation. Error is less than 0.5 °,so the double closed loop speed position control system meets the performance requirements.

IV. CONCLUSIONS

In this paper,a variable parameter PID digital control method was proposed for the double closed loop control system of the speed position, According to the concrete formula, have Mathematical modeling, simulation research, single and double closed loop experimental comparison test .By setting a fixed angle and swinging continuously carried out the whole joint debugging, experimental results show that single closed loop control system is unstable and the error is large,which exists obvious chase pendulum.Instead, the control method of double closed loop speed position in this paper enables the platform to run stably, without obvious chasing pendulum, and the error precision meets the system requirements, it can achieve desired requirements.

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