Positioning Accuracy Analysis for a DP Platform with Roll and Pitch Motion Control

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ABSTRACT

In dynamic positioning systems, the horizontal plane motions, including surge, sway and yaw, are commonly taken into consideration. However, the vertical plane motions, especially roll and pitch, which are induced by thruster force may have influence on positioning of marine constructions as well. Horizontal plane motion control with roll and pitch control might be a solution to this problem. Roll and pitch velocity and acceleration are feedback signals to generate the control forces in the horizontal plane. The effect of the additional roll and pitch motion control law on the positioning accuracy of the horizontal plane remains uncertain. In this paper the analysis of roll and pitch motion of a dynamic positioned semi-submersible with roll and pitch motion control is made. The mechanism of the effect under the roll and pitch control law is presented in the time domain. It is shown that the effect is determined by the attitude of the semi-submersible, as well as the horizontal control force at that moment. The analysis of the influence on positioning accuracy is conducted based on the statistical analysis of the time-domain motions.

KEY WORDS: dynamic position, roll-pitch, time domain simulation.

INTRODUCTION

As one of the main mooring methods, the dynamic position system has been widely used on offshore vessels and platforms, especially semi-submersible. The purpose of it is to keep vessels in the desired position with minimal fuel consumption, which usually regard the control objective as a three-degree-of freedom problem in the horizontal plane, in surge, sway and yaw respectively. For references see (Sargent and Cowgill 1976); (Balchen, Jenssen et al. 1980);(Fossen 1994);(Sørensen, Sagatun et al. 1996);(Strand, Sørensen et al. 1998) and (Fossen 2011). However, for certain offshore constructions, especially whose water-plane area is small and metacentric height is low, their hydrostatic restoring forces are small when compared to the inertia forces. And an unintentional coupling phenomena between the vertical plane and the horizontal plane will be invoked. So in (Sørensen and Peter Strand 2000), a new multivariable control law accounting for both horizontal and vertical motions is proposed. And a significant roll-pitch damping can be achieved. Then in (Xu, Wang et al. 2013), a new control strategy is presented which include the angular velocity and acceleration of roll and pitch motions. Both of the papers have discussed the influence of their control strategies on horizontal motions. But the analysis of the influence on positioning accuracy is not enough and neither of them two have described the mechanism of the effect.

In this paper, the control strategy is the same with (Xu, Wang et al. 2013), but their results and computations are further developed and analyzed. The mechanism of the effect under roll and pitch control law is also discussed. More attention are paid on the analysis of the influence on position accuracy.

MATHEMATICAL MODELLING

Kinematics

In order to define the motion of the platform, three kind of coordinates used in this paper are illustrated in Fig. 1 and described below.

● The Earth-fixed reference frame is denoted as the $X_E Y_E Z_E$-frame which can be regarded as the global coordinate for the whole system.

● The vessel-parallel frame $X_V Y_V Z_V$-frame is fixed in the global coordinate $X_E Y_E Z_E$-frame. The angle $\psi_d$ is the desired heading angle and the position $x_d$ and $y_d$ are desired position of the platform.

● The body-fixed frame $X_G Y_G Z_G$-frame is fixed to the vessel body with its origin at the mean oscillatory position $(x_G, 0, z_G)$, the x axis points to the front side of the semi-submersible and the y axis points to the portside. So the positive side of the z axis point to the topside of the platform.

The transformation between the body-fixed frame and the earth-fixed frame can be used to describe the motions of the platform. It contains both linear and angular velocity transformations. Then the kinematic equations can be expressed in the vector form as: