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Model Experiments on Dynamic Positioning System Using Gain Scheduled Controller

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ABSTRACT

This paper is concerned with the dynamic position control for a semisubmersible platform model using a gain scheduled H_∞ controller. Offshore floating platforms are required to control their position within allowable deviation against the external forces of ocean surface current, wind and waves. A dynamic positioning system using thrusters is generally employed for this. The purpose of the control is to maintain a given position or to adjust the position using thruster activity that does not respond to linear wave force. Based on a rotation matrix in yaw, a linear model with 4 vertices was introduced. The problem was formulated in the framework of a multimodel-based design of the H_∞ control law with pole region constraint. Methodology based on LMI (linear matrix inequality) was used to solve the problem. The gain scheduled H_∞ controller was implemented by interpolation of the 4 vertex controllers. Model experiments with some successful results are shown.

INTRODUCTION

Semisubmersible platforms are widely used in the exploration and development of ocean resources, and many such platforms are now in operation. They are required to maintain their position within a given watch circle, and to rectify this position against the external forces of ocean current, wind and waves.

PID control is the standard control in the industry. The PID parameters are easy to adjust on the spot to deal with any problem. However, this control algorithm depends on the arrangement of the thrusters, because it can only deal with a single-input/single-output system. Moreover, the design of a PID controller and that of a filter are considered separately. In our last paper (Hyakudome et al., 2000), we formulated the problem in the framework of a single model-based design of H_∞ control law and designed a fixed linear controller. H_∞ control algorithm can deal in detail with the multi-input/multi-output system and design frequency characteristics. (An effect of a filter is included in the controller.) The controller worked well near an equilibrium point ($\psi^* = 0°$: the controller was designed at this point), but it did not enable the platform to rotate in response to a large magnitude command. The reason is that the linear mathematical model used in the design of the controller changes moment by moment during the turning round. We introduce here a linear model with 4 vertices based on a rotation matrix in yaw. The problem was formulated in the framework of a multimodel-based design of the H_∞ control law with pole region constraint. Methodology based on LMI (linear matrix inequality) was used to solve the problem, since it can treat multimodel and multi-objective specifications, and 4 vertex controllers were designed. The gain scheduled H_∞ controller was implemented by interpolation of these 4 vertex controllers. Model experiments were carried out in oblique incident waves and current, and the gain scheduled H_∞ controller enabled the platform to rotate in response to the command for a large angle (±36°). To turn more than ±36°, rotation was actualized by switching the controller every 36°.

LINEAR MATHEMATICAL MODEL OF SEMISUBMERSIBLE PLATFORM

The nonlinear equations of motion have been shown in detail by Nakamura et al. (1994, 1995) and Hyakudome et al. (2000). From the nonlinear equations, the linear mathematical model in which $\cos\psi^*$, $\sin\psi^*$ enter in an affine manner is described as follows:

$$\begin{cases} \dot{x} = E^{-1}A'x + E^{-1}B'\begin{bmatrix} u_1 \\ u_2 \end{bmatrix} \\ \quad = E^{-1}(A'_0 + \cos\psi^* A'_{\cos\psi^*} + \sin\psi^* A'_{\sin\psi^*})x + E^{-1}B'u \\ \quad \equiv E^{-1}(A'_0 + a_1 A'_{a_1} + a_2 A'_{a_2})x + E^{-1}B'u \\ \quad = (A_0 + a_1 A_{a_1} + a_2 A_{a_2})x + Bu \\ \quad \equiv A(a_1, a_2)x + Bu \\ y = Cx \end{cases} \tag{1}$$

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KEY WORDS: Dynamic positioning system, gain scheduled H∞ control, controller switching, model experiments, semisubmersible platform.