Field Experiments on Motion Control Systems of the Towed Vehicle "Flying Fish"

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ABSTRACT

A high speed towed vehicle "Flying Fish" is being developed to measure chemical and physical properties of the ocean. The motion control system is based on the PID (proportional integral differential) control method or the LQI (linear quadratic integral) control method. LQI control system required an accurate mathematical model of the vehicle's motion, and the model therefore, was improved through field experiments. Field experiments were carried out in the summer of 1997 in the Japan Sea. The hydrodynamic coefficients were estimated using the measured vehicle's motion, ship's motion and tension of the towing cable. Results of the field experiment were compared with numerical simulations to research the accuracy of the model used in the design stage of the control system. The results of numerical simulation using the hydrodynamic coefficients obtained from the field experiment show good agreement with the field experiment. Some problems on the design of the motion control system are also discussed.

KEY WORDS

Towed Vehicle, Hydrodynamic Coefficient, Motion Control, Field Experiment, Numerical Simulation

1 INTRODUCTION

"Flying Fish" is a towed vehicle used to measure chemical and physical properties in the ocean. The high speed system offers the advantage of enabling us to measure a wide area in a short time (Koterayama, et al., 1994). The design of the motion control system of the vehicle is based on a mathematical model of the vehicle's motion obtained from model experiments and field experiments is important to confirm the accuracy of the mathematical model. In this paper, results of the field experiment are compared with numerical simulations to research the accuracy of the model used in the design stage of the control system. Some hydrodynamic coefficients are re-estimated using the field experiment data, and problems with the design of the motion control system based on LQI control method are discussed.

Section 2 and 3 describe about a mathematical model of the vehicle and the design of the control systems using the model. The outline of the field experiment and estimation of the hydrodynamic coefficients using the field experiment data are expressed in section 4 and 5. Section 6 describes results of the field experiment and comparison with numerical simulations. Section 7 is conclusions.

2 A MATHEMATICAL MODEL OF THE TOWED VEHICLE

The motion of the vehicle is described based on a coordinate system fixed on the body (Figure 1). Origin of the coordinate system is located in the center of the main wing and x, y and z axes are defined forward, rightward and downward of the body, respectively. This paper deals only with longitudinal motion. The longitudinal motions of the vehicle are described based on the coordinate system as follows (Newman, 1977, Ohkus, et al., 1987):

\[
\begin{bmatrix}
  m + A_{11} & 0 & m z_G + A_{15} \\
  0 & m + A_{33} & -m z_G + A_{35} \\
  m z_G + A_{51} & -m z_G + A_{53} & I_{yy} + A_{55}
\end{bmatrix}
\begin{bmatrix}
  u \\
  \dot{u} \\
  \dot{q}
\end{bmatrix}
= \begin{bmatrix}
  F_x \\
  \dot{F}_x \\
  M_y
\end{bmatrix}
\]

where

\[
F_x = -(m + A_{33}) q w + (m z_G - A_{35}) q^2 \\
- (m - \rho V) g \sin \theta + X_{u \omega} u^2 + X_{u \omega} w^2 \\
+ X_{\delta \omega} \delta^2 + X_{\gamma \gamma} \gamma^2 + X_T
\]