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An Advanced Adaptive Control System for Activated Anti-Rolling Tank

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ABSTRACT

This paper attempts to apply the adaptive control theory to the design of a control system for a ship's rolling motion using an activated anti-rolling tank. In this theory, model parameters of the system are estimated sequentially on the basis of the least squares method. Numerical simulations are made based on the SOLA-SURF scheme, and it is confirmed that the system can effectively decrease the rolling angle over a wide frequency range and can cope with changes in motion characteristics by application of the theory to the control of an activated anti-rolling tank device.

INTRODUCTION

The purpose of this paper is to propose a design concept of a ship stabilizing device which uses an activated anti-rolling tank. Many types of stabilizers for ships — such as a gyro-stabilizer, weight stabilizer, fin stabilizer, anti-rolling tank and others — have been tested, and in recent years the fin stabilizer has generally been used to reduce the rolling motion of a ship. However, this cannot effectively reduce the rolling motion of a ship sailing at low speed or for a ship at anchor. The stabilizing performance of the anti-rolling tank, in contrast, does not depend on the forward speed of the ship, and therefore this device can be fitted to any type of ship operating at any speed.

Tank stabilizing devices are passive or activated. The passive type is not as efficient a stabilizer over a wide wave frequency range. To obtain beneficial reduction of the ship rolling motion over a wide range of speeds and wave frequency, the authors applied the adaptive control theory (Landau and Tomizuka, 1981) to the design of a rolling motion control system using an activated anti-rolling tank. In this adaptive control system, model parameters of the plant (ship and tank) are estimated sequentially on the basis of the least squares method, so the controller can cope with changes of plant parameters due to oceanographic conditions or a ship's loading conditions. The SOLA-SURF scheme, which is based on the finite difference method, is used to calculate the dynamical motion of liquid in an anti-rolling tank; the ship rolling motion is calculated by the ordinary strip method.

A series of numerical simulations is carried out to investigate the frequency characteristics of the activated anti-rolling tank system, and several considerations in the design of the system are discussed. The problem is discussed in two dimensions.

BASIC EQUATIONS

We will consider the activation of an anti-rolling tank installed on a ship. The tank is a U-shaped type, with two side tanks and a channel as shown in Fig. 1. The tank is activated by an impeller system fitted on the center of the channel. The impeller drives fluid in the tank in a reciprocating motion. The coordinate system is adopted as shown in the figure: A moving system *o-yz* having its origin at the point of the rolling axis through the center of gravity of the ship *G* is used.

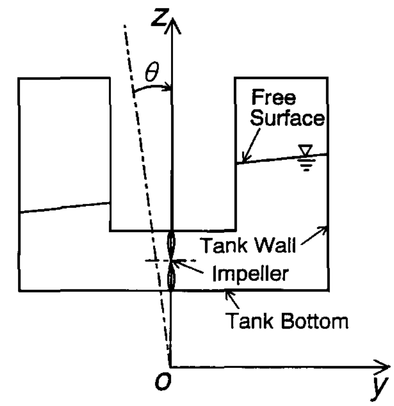

Fig. 1 Coordinate system for activated anti-rolling tank

The basic equations of fluid motion in a tank installed on board a ship are derived, assuming the fluid to be incompressible two-dimensional flow. The Navier-Stokes equations and the mass continuity equation are given in terms of cartesian coordinates (y, z) as follows:

$$\frac{\partial v}{\partial t}=-\frac{\partial v^2}{\partial y}-\frac{\partial vw}{\partial z}-\frac{\partial \phi}{\partial y}+\nu\left(\frac{\partial^2 v}{\partial y^2}+\frac{\partial^2 v}{\partial z^2}\right)+g_y \tag{1}$$

$$\frac{\partial w}{\partial t}=-\frac{\partial vw}{\partial y}-\frac{\partial w^2}{\partial z}-\frac{\partial \phi}{\partial z}+\nu\left(\frac{\partial^2 w}{\partial y^2}+\frac{\partial^2 w}{\partial z^2}\right)+g_z \tag{2}$$

$$D\equiv\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \tag{3}$$

where v and w are y– and z– components of fluid velocity, p is fluid pressure, and ν is the coefficient of kinematic viscosity of fluid.

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KEY WORDS: Anti-rolling tank, adaptive control, impeller, activated control, finite difference method.