

Parametric Identification for a Roll Instability in a Series S60-70 Ship

A.H. Nayfeh, J. Fung, M.R. Hajj and D.T. Mook
Virginia Polytechnic Institute and State University
Blacksburg, VA, USA

ABSTRACT Roll instabilities that are caused by nonlinear interaction mechanisms must be modeled properly for the design and safe operation of seagoing vessels. Two different mechanisms that cause roll instabilities in ships are described. Equations of motion for a parametric wave excitation mechanism are given. An approximate solution based on the method of multiple scales is presented. Different simulations using the Large Amplitude Motions Program (LAMP) code are conducted to determine linear parameters of the heave, pitch, and roll response. A methodology for nonlinear system identification that combines the method of multiple scales and higher-order statistics is proposed.

KEY WORDS: Parametric identification, parametric resonance, nonlinear system identification, perturbation methods, multiple scales, higher-order spectra, bispectra

I. INTRODUCTION

It has been well documented that nonlinear resonance conditions between heave, pitch, and roll motions could lead to large roll responses. These roll motions can impede on-board operations and even cause capsizing. To reduce or prevent the effects of these motions, one needs prediction and control schemes. Such schemes can only be effective if the relevant mechanisms are correctly modeled. Because these mechanisms are primarily nonlinear, such models need to accurately describe the nonlinear resonances between the heave, pitch, and roll motions. Consequently, any system identification process must be able to quantify such resonances.

In this work, we outline a methodology for the system identification of a roll instability in a series S60-70 ship. In Section II, we discuss how roll instabilities can result from

either autoparametric resonances or parametric resonances. We present the governing equation for the parametric mechanism and an approximate solution based on the method of multiple scales. In Section III, we discuss the numerical simulations conducted, using the LAMP program developed by the Scientific Applications International Corporation (SAIC), to study the parametric mechanism. In Section IV, we identify the linear parameters governing this system. Finally, we propose a methodology, combining the method of multiple scales and higher-order spectra, for identification of the nonlinear system parameters.

II. TWO MECHANISMS OF ROLL INSTABILITIES

Nayfeh et al (1973), Mook et al (1974), Nayfeh (1988), and Oh et al (1993) used the method of multiple scales to determine the steady-state responses and stability of ships under different wave excitations and heave, pitch, and roll coupling conditions. The results of these studies show that there are many resonance conditions under which the roll response can grow to significantly large amplitudes. These roll instabilities can be produced by different mechanisms. In one mechanism, considered by Nayfeh et al (1973) and Mook et al (1974), the encounter wave frequency is near the pitch natural frequency. The pitch natural frequency, in turn, is near twice the roll natural frequency. Under these conditions, there is an autoparametric resonance between the two modes. Consequently, there is a continuous energy exchange between them. In the second mechanism, considered by Oh et al (1993), three degrees of freedom were taken into consideration. In this case, the encounter wave frequency is near twice the roll natural frequency, but the heave and pitch natural frequencies are away from twice the roll natural frequency. Under these conditions, there is no autoparametric resonance between the heave, pitch, and roll modes. Instead,