The Effect of Excitation Modelling in the Parameter Estimation of Nonlinear Rolling

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ABSTRACT

In this paper the effect of the excitation modelling on the fitting capability of the nonlinear roll motion equation to experimental data is studied. Several frequency dependent and constant effective wave slope coefficients are derived for five different scale models corresponding to different ship typologies by a Parameter Identification Technique. The frequency domain behaviour of the obtained coefficients is discussed and compared with linear diffraction (strip theory) results and I.M.O. suggested values. It appears that a mathematical modelling with constant damping parameters and frequency dependent excitation could give very good results. As regards the excitation parameters, a common trend for slender bodies is evidenced.

Key words: Nonlinear Dynamics, Roll Motion, Simulation, Parameter Identification.

INTRODUCTION

Modern approaches to ship safety attribute a great importance to the development of procedures for the simulation of large amplitude motions [Francescutto, 1992; Francescutto, 1993]. These, and in particular rolling motion exhibit highly nonlinear features and up to now deny the many attempts to develop a fully nonlinear hydrodynamic code.

A medium term research plan with the objective to investigate the possibility of development of high level semiempirical approaches to nonlinear rolling is in progress at University of Trieste. Particular attention is presently devoted to the study of the reliability of a simulation based on the isolated roll motion equation for a ship in beam sea condition and to the problem of parameter identification from experiments on scale models in towing tank. To this end, a concentrated parameters mathematical model for nonlinear rolling is discussed and a parameter identification technique has been developed, based on the least squares fit of the numerical solution of the differential equation to the experimental results.

In a previous paper [Contento et al., 1996], this operation was conducted on a set of experimental data on large amplitude rolling of a RoRo vessel. A parameter identification technique was applied separately on the results at constant wave steepness and at constant wave frequency. The results indicated that an extremely good simulation capability could be achieved by introducing a frequency dependence on the damping coefficients and a wave steepness dependence on the excitation.

Looking for a more simplified mathematical modelling, possibly using as much as possible constant coefficients, the whole problem has been reanalysed according to the following items:

- adoption of a brand new motion measuring system that avoids any gravity referenced device with the exception of the equilibrium position. This should reduce the possible sources of bias connected with lateral motions (heave and sway) in the tails of the roll resonance peak.

- adoption of a new search strategy for the “optimum” set of parameters based on the simultaneous cross analysis of all the data pertaining to a ship model in the same loading condition. In this way the curves at constant wave frequency and at constant wave steepness both contribute to the production of “averaged” coefficients, so avoiding local fluctuations and some side effects connected with undiscovered correlations between the two separate sets of coefficients.

Bearing this in mind, an ad hoc campaign of experiments on five scale models (two RoRo ferries, a destroyer, a frigate and a fishing vessel) has been conducted, analysing the rolling motion in a regular beam sea. The experiments have been conducted on a grid of values of frequency and steepness of the excitation, so that the analyses at constant frequency, at constant steepness and crossed are possible. The results of the Parameter Identification Technique (PIT) applied to the experimental data allow some conclusions on the mathematical modelling of the excitation in the frequency domain. The asymptotic behaviour of the excitation at large nondimensional frequencies is discussed according to the results from the experiments and the performance of a proposed model is checked. Analogies and differences between absolute and relative angle description are evidenced as well. Finally the obtained “effective wave slope coefficients” of the five ship models are compared with those from a traditional strip theory-based code (linear diffraction in inviscid fluid) and with the values suggested by the I.M.O (Weather Criterion).

MATHEMATICAL MODELLING OF SHIP ROLLING

The roll motion equation is generally derived under the assumption that the different contributions (added inertia, damping, restoring and excitation) can be separated [Kishev and Spasov, 1981]. Two different