Prediction of Parametric Roll Resonance by Multilayer Perceptron Neural Network

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ABSTRACT

Parametric roll resonance is a ship stability related phenomenon that generates sudden large amplitude oscillations up to 30-40 degrees of roll. This can cause severe damage, and it can put the crew in serious danger. The need for a parametric rolling real time prediction system has been acknowledged in the last few years. This work proposes a prediction system based on a multilayer perceptron (MP) neural network. The training and testing of the MP network is accomplished by feeding it with simulated data of a three degrees-of-freedom nonlinear model of a fishing vessel. The neural network is shown to be capable of forecasting the ship’s roll motion in realistic scenarios.

KEY WORDS: parametric roll; prediction systems; artificial neural networks; fishing vessels.

INTRODUCTION

Parametric roll resonance is a well known phenomenon that has gathered great attention in the last years due to the real threat suffered by container ships in common passage conditions, which were generally considered of no danger. The resonance is most likely to happen when the ship is sailing in head or stern seas under some specific conditions as: the wave encounter frequency is approximately twice the ship’s natural roll frequency; the wavelength is almost equal to the ship length; the wave amplitude is larger than a ship dependent threshold. When these conditions are fulfilled, the periodic alternation of wave crests and troughs amidships brings about dramatic changes in ship transverse stability, which in turn determines a sudden and quick growth of roll oscillations. The extreme roll motion can lead to ship structural and cargo damage, it can determine risky situations for the crew and, in the worst cases, can lead to capsizing.

The susceptibility of a ship to develop parametric roll is determined by the amplitude of the heeling arm variations, which depend on the hull form. Modern container carriers are particularly prone to parametric roll resonance due to their hull shapes – large bow flare, overhanging stern, wall-sided midship sections – which are designed to achieve an optimal trade-off between high service speed and maximum container payload above deck (Shin et al., 2004, France et al., 2001, Nielsen et al., 2006). Another type of vessel very susceptible to this phenomenon is fishing vessels. Due to regulatory limitations, their hull forms include hanging sterns and full midbodies in order to maximize both working space and storage capacity. The immersion of the stern as waves pass leads to large changes in waterplane area, which, in turn, causes the onset of parametric resonance in roll.

Few examples of accidents happened because of parametric roll were reported in literature. The most notorious is definitely the accident occurred to the APL China post-Panamax container ship, which suffered cargo losses for more than 50 million dollars (France et al., 2001). The PCTC Aida experienced two episodes of violent roll motions, hitting roll angles larger than 50 degrees (IMO, 2007). Parametric rolling may also have been the cause of severe material damage and injuries to passengers and crew of cruise ships Grand Voyager and Pacific Sun (MAIB, 2009).

By contrast, there is no evidence about parametric rolling involving fishing vessels. Probably this is due to the fact that these ships usually have small stability margins, thus a severe parametric roll episode could easily lead to capsizing and sinking, leaving no trace of the phenomenon. However, many studies demonstrated that fishing vessels are prone to develop parametric roll (de Juana Gamo et al., 2005), which implies a high risk for the ship and its crew.

One of the main characteristics of parametric roll is its very sudden onset. It develops in just few rolling cycles and there are few signs that can timely suggest the crew that the resonance is occurring. Therefore the exigency of a system that can predict the inception of a parametric rolling episode soon enough to give the crew time to take corrective actions and prevent heavy roll motions is clear.