Early Detection of Parametric Roll Resonance on Container Ships

Parametric roll resonance on ships is a nonlinear phenomenon where waves encountered at twice the natural roll frequency can bring the vessel dynamics into a bifurcation mode and lead to extreme values of roll. Recent years have seen several incidents with dramatic damage to container vessels. The roll oscillation, which is subharmonic with respect to the wave excitation, may be completely unexpected and a system for detection of the onset of such resonance could warn the navigators before roll angles reach serious levels. Timely warning could make remedial actions possible, such as change the ship’s speed and course, to escape from the bifurcation condition. This paper proposes nonparametric methods to detect the onset of roll resonance and demonstrates their performance. Theoretical conditions for parametric resonance are revisited and are used to develop efficient methods to detect its onset. Spectral and temporal correlations of the square of roll with pitch (or heave) are demonstrated to be of particular interest as indicators. Properties of the indicators are scrutinized, and a change detector is designed for the Weibull-type of distributions that were observed from a time-domain indicator for phase correlation. Hypothesis testing for resonance is developed using a combination of detectors to obtain robustness. Conditions of forced roll and disturbances in real weather conditions are analyzed and robust detection techniques are suggested. The efficacy of the methodology is shown on experimental data from model tests and on data from a container ship crossing the Atlantic during a storm.

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