

# Heave-Excited Rolling Motion of a Rectangular Vessel in Head Seas

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## ABSTRACT

A two-degree-of-freedom nonlinear numerical model is developed to simulate the heave-excited rolling motion of a vessel. The geometrical concepts and global analysis methods of nonlinear dynamics are applied to gain some insights of the behavior of ship rolling. Parametric resonance, jump and bifurcations of the types of fold, period-doubling and pitchfork are observed to occur in the Poincaré mapping of the simulated rolling motions. Chaotic motions are also predicted by the numerical model.

## INTRODUCTION

Parametric resonance of rolling motions has long been recognized as one of the most dangerous modes of ship-capsizing. Reviews of both the experimental and analytical studies of ship rolling were recently given by de Kat and Paulling (1989) and Nayfeh (1988). In the analysis of rolling motions, the earlier approach of assuming linear restoring moment and no feedback from roll to heave (or pitch) led to a Mathieu equation for the roll, with the heave (or pitch) treated as a prescribed parametric excitation. Instability regions in the parametric planes were then obtained from the Mathieu equation (Paulling and Rosenberg, 1959; Blocki, 1980). This approach gave qualitative descriptions of roll instabilities but could not explain some of the complicated behavior associated with large rolling motions.

Nayfeh, Mook and Marshall (1973) and Mook, Marshall and Nayfeh (1974) investigated the coupled roll-pitch motions. They demonstrated the existence of a saturation phenomenon involving an energy exchange between the indirectly excited roll and the directly excited pitch motion, when the pitch frequency was twice the roll frequency and the pitch motion was excited near its resonance.

Thompson, Rainey and Soliman (1990) proposed recently that the phenomenon of ship instability and the post-instability behavior could be quantified by applying the new geometrical concepts of nonlinear dynamics (Thompson and Stewart, 1986). They studied a single degree-of-freedom system for the rolling motion of a ship and showed that the problem of ship-capsizing could be understood based on the concept of basin erosion. The transitions of basins of attraction which represent globally the transient behavior of the system can be monitored and quantified as an index of capsizability.

In this paper, the coupled problem of roll and heave is studied. The model considered is a free-floating rectangular vessel in a head or following sea condition. Due to symmetry of the model,

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KEY WORDS: Heave-roll motion, parametric excitation, bifurcation, nonlinear dynamics, chaotic motion.

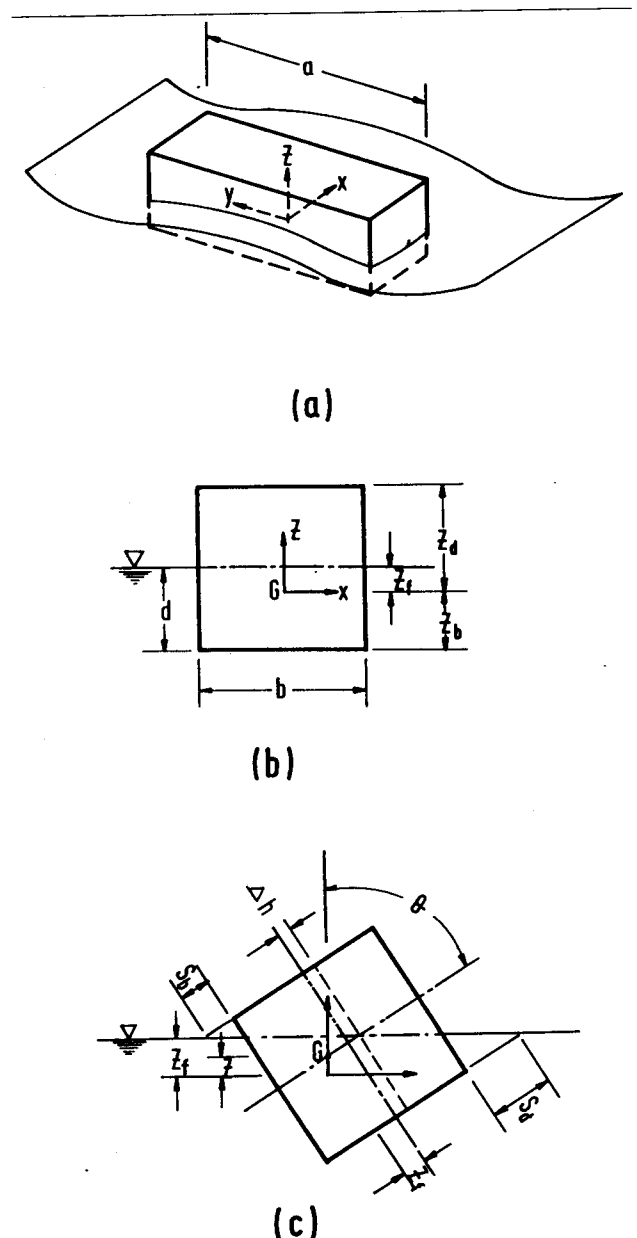


Fig. 1 Large roll and heave motions of vessel in waves