Numerical Study on the Parametric Rolling of Post-Panamax Class Containership Based on Mathieu Instability

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ABSTRACT

An extensive numerical study on the possibility of parametric rolling of containership was conducted based on Mathieu instability. For Post-Panamax class containership, numerical analysis using a fully nonlinear model and a simplified dynamic mathematical model, and the prediction of the possibility of parametric rolling based on susceptibility criteria using theoretical formulas were performed. The analysis was conducted for a wide range of wave frequencies, including those predicted to cause parametric rolling. Based on the prediction result of the possibility of parametric rolling for each model, the difference was analyzed by comparing the prediction results among the models. In addition, the characteristics of roll motion according to the magnitude of the initial disturbance and the possibility of parametric rolling were quantitatively assessed using a fully nonlinear model. The characteristics of roll motion and the possibility of parametric rolling were evaluated for head-sea condition and quartering-sea condition under the same wave condition. The results of this study clearly reveal the coincidence of and difference between the analysis results at each level of numerical analysis by presenting the analysis results obtained based on different numerical models pertaining to the possibility of the parametric rolling of the target containership. The findings of this study contribute foundational data for the initial design and operational performance evaluation of containerships of comparable size in the future.

KEY WORDS: Mathieu instability; parametric rolling; containership; fully nonlinear model; simplified dynamic mathematical model; initial design.

INTRODUCTION

With the rapid growth of the global economy and the active trade between regions, the volume of goods transported has been increasing daily. This increasing volume is transported to each region through land transport, air transport, and sea transport; furthermore, sea transportation using ships accounts for a significant portion of the total volume. In particular, most of the general cargo that we encounter almost every day in our daily life is transported through containerships. In the past, the size of the small containerships approximated that of the large containerships of 10,000 TEU or more in the 2010s, and reached the operational level of ultra-large containerships of 24,000 TEU class. From the perspective of ship operators, the trend of enlargement is an important axis for securing the economic efficiency of containership operation. Furthermore, the operation of medium-sized containerships of the optimal size for interregional goods trade over a certain size is also an important axis (Monthly Maritime Korea, 2015). A medium-sized containership refers to a containership of the Panamax class to the Post-Panamax class, and a containership of this size can transport approximately 4,000–8,000 TEU containers (Wikipedia, 2019). Although sea transportation through containerships is mostly conducted under mild sea conditions, there are cases where it is unavoidably operated under rough sea conditions. In case of operation under bad weather, container loss may occur during sea transportation. However, under a condition where the wave height is not relatively high, the excessive roll motion of the vessel may cause container loss. Such cases have been frequently reported in the past. In recent years, with the development of technology and accumulation of containership operation experience, it has been found that the metacentric height of the ship, vessel speed, wave height, roll damping of the ship, and the initial roll angle are the main causes of this phenomenon (Umeda, 2004; Rodríguez, 2007). Nevertheless, a number of similar accidents still occur, and related studies are being conducted continuously. Owing to the recent ship accident that is estimated to be a parametric rolling phenomenon (France et al., 2003; Van Laarhoven and B.J.H., 2009), Moideen et al. (2012, 2013, 2014) and Somayajula and Falzarano (2014, 2015b) performed a related study, and the issue of ship roll motion was re-raised. Shipowners, classifications, and shipyards are acutely aware of the requirement for in-depth consideration of the parametric rolling phenomenon in the ship design process. However, in the initial design process, various design items such as the alignment of ship and operating loading conditions are changed. Considering the time and cost, it is impossible to perform both simulation and experiment on the ship under design for each changed condition. It is economically ideal to conduct the simulation using a simple model to the extent possible, and establish a detailed design later. Parametric rolling phenomenon is known to occur when an initial disturbance is provided in the vicinity of a period in which the encounter period of the incident wave is about half of the roll natural period of the ship under the bow wave condition (France et al., 2003; Lee et al., 2005;