Study on Hydroelasto-Plastic Test and Hysteretic Test of a Ship Model in Regular Waves by Changing Wavelength

Yu Huang, Wei-qin Liu*, Xue-min Song
Departments of Navel Architecture, Ocean and Structural Engineering, School of Transportation, Wuhan University of Technology
Wuhan, Hubei, China

ABSTRACT

Large waves used to cause a lot of ship accidents and casualties. Nonlinear dynamic strength of ship structure in waves have attracted attention from more and more researchers recently. Hydroelasto-plastic experiment in regular waves by changing wave height has been completed in previous work. The research focus in this paper is to carry out hydroelasto-plastic test in regular waves by changing wave length. Hydroelasto-plastic model is designed to generate large deformation in tank regular waves. It is made up of two rigid ship strips at both ends and an elastoplastic hinge at midship. An experimental program is determined firstly, then a series of experimental cases varies from 0.5 to 3 times wave length-ship length ratio was performed by changing wave length. The time-domain rotation angle of hydroelasto-plastic ship model is obtained. The nonlinear accumulated collapse response was caused when the ship encounters large cyclic waves. A hysteretic test should be performed to study the nonlinear strength of subsequent waves. The hysteretic test using displacement loading method is performed to acquire hysteresis characteristic of the elastoplastic hinge. The hysteretic results are used to determine the post ultimate strength and evaluate the residual capacity of elastoplastic hinge under cyclic wave load. Thus, the time domain non-dimensional vertical bending moment can be transformed based on the hysteretic results and time-domain rotation angle history. Finally, the relationship between nonlinear structural responses and wave length is obtained.

KEY WORDS: regular waves; hydroelasto-plastic; rotation; VBM; wave length; hysteresis.

INTRODUCTION

With the development of global economic integration, goods trade and transportation business have been generated among various countries and regions in the world. As the main means of global cargo transportation, the safety and reliability of ships are not only related to the safety of cargo and property on board, but also related to the Marine environment and ecological protection. The hull structure would collapse if the external wave load suffered is greater than the ultimate carrying capacity of the ship structure in harsh ocean environment, resulting in the loss of the life and property. From 2005 to 2014, more than 1,200 large ships encountered maritime disasters, and nearly 10% were believed to be related to structural damage. For instance, in the evening of November 2002, the oil tanker "prestige" with 77000 tons of fuel encountered harsh storm in northwestern Spain 9 km from the shore, causing Prestige broke into two pieces. The accident caused 20 million gallons of oil was dumped into the sea, the coast of Spain was seriously polluted. These disasters facilitated the release and implementation of common structural rules (IACS, 2005). The trend of container ship design is towards large aspect ratio and large deck opening to transport as much cargo as possible, which causes the ship more flexible. It is essential and necessary to evaluate the structural strength. Many researchers devoted themselves to propose reliable and efficient method to assess the safety and reliability of ship structure.

The theory of hydroelasticity can solve the motion/load of ships under waves. Heller-Jr and Abramson (1959) defined the hydroelasticity of ships as the study of the interaction between inertial forces, hydrodynamic forces and elastic forces. The hydroelasticity of ships regards the flexible hull structure and the surrounding flow field as a whole system interacting with each other. And then the dynamic characteristics of ship structures, such as ship motion, wave load, structural deformation, stress and strain, and fatigue performance, can be predicted and evaluated more reasonably. Wu (1984) proposed the generalized fluid-solid interface condition, and developed a three-dimensional hydroelasticity theory suitable for analyzing the dynamic response performance of any three-dimensional variable body in waves. The theory of hydroelasticity can simultaneously calculate the motion and deformation responses of hull structures under waves, which can be solved quickly. However, since the hydroelasticity theory are based on the modal superposition method, only the linear strength response of the hull structure can be calculated, and the nonlinear characteristics of the hull structure such as material nonlinearity and geometric nonlinearity cannot be considered. It is not suitable for the nonlinear strength problem of the structure, and the dynamic collapse response of the hull structure under waves cannot be solved.

The traditional method to assess the ultimate strength of ship structure in waves is to calculate the wave-induced load and the carrying capacity of ship structure separately, some calculation accuracy is sacrificed. The hydroelasto-plasticity method is a feasible method can consider the interaction between nonlinear fluid and structure to