Longitudinal Strength of Container Ships under Combined Torsional and Bending Moments

Yoshiteru Tanaka*, Takahiro Ando†, Yousuke Anai*, Tetsuya Yao**, Masahiko Fujikubo*** and Kazuhiro Iijima***

* Structure and Material Department, National Maritime Research Institute, Mitaka, Tokyo, Japan
† Department of Naval Architecture and Ocean Engineering, Osaka University, Suita, Osaka, Japan

ABSTRACT

This paper presents the results of an experimental study to evaluate the effect of torsional moment on the ultimate strength of container ships in longitudinal bending. The progressive collapse tests are conducted using 1/13-scale three-hold models referring to a Post-Panamax container ship. The models are fixed to the rigid wall at the aft end (cantilever beam) and a couple of loads are applied to the fore end so as to generate both torsional and vertical bending moments. Several loading conditions which vary the ratio of torsional and bending moments are adopted for the progressive collapse tests and the nonlinear finite element analyses using LS-DYNA. From the results of collapse tests and numerical simulations, the progressive collapse behavior including the warping-strain distribution and the ultimate strength interaction relationship is examined.

KEY WORDS: ultimate strength; torsional moment; bending moment; container ship; scale model; progressive collapse test; nonlinear FEA.

INTRODUCTION

The steady increase of global container traffic has boosted the demand for larger container ships. Currently the biggest container ship in the world can carry up to 14,000 TEU. Probst (2007) predicted that the break-even point will be governed by economics and not by technical considerations. However, Probst (2006) demonstrated that aspects such as structural integrity, maneuverability, propulsion and especially operational management must be carefully considered at an early design stage. The structural feasibility of 13,400 TEU container ships has been proven and the investigation verified that a further enlargement of Post-Panamax container ships is possible.

Under such situation, the 4,400 TEU container ship MSC Napoli encountered heavy seas and suffered structural failure while on passage through the English Channel on January 2007. Though an investigation that was carried out by the Marine Accidents Investigation Board (MAIB, 2008) identified a number of factors which contributed to the failure of the hull structure, it was reported that the vessel’s hull did not have sufficient buckling strength in way of the engine room. MSC Napoli seemed to have insufficient safety margin between the hull’s design loading and its ultimate strength against vertical bending moment. However, it is necessary for the large container ships built in recent years to take hull girder ultimate strength against torsional moment into consideration, because they have structural characteristics such as large hatch openings, fine hull shape, large bow flare and overhanging stern.

Shi et al (2006) demonstrated that extra design efforts are indispensable for enhancing structural integrity and safe operations of large container ships that possess a large bow flare and a low torsional rigidity. Proper and rational classification assessment requires that first-principles based engineering calculation methods be used to increase the standard classification review. The scope of the essential engineering assessment should encompass full-ship finite element analysis under nonlinear wave loads, spectral fatigue analysis, transient and impact load analysis, finite element lashing analysis, parametric roll prevention and vibration analysis. The authors stipulated that design and operation of large container ships are beginning to benefit from technological advances in hydrodynamics and structural analysis. Yu et al (2006) investigated the envelope of wave-induced sag-hog moments; specifically, whether the nonlinear effects due to hull form and forward speed are properly reflected. Direct calculation methods are often used by ship designers to apply the ship motions and wave loads calculated from nonlinear sea keeping theory, and then the finite element structural analysis is carried out to assess the structural integrity of the vessel.

One of the most important items to be considered in the structural design of container ships is the strength of hatch corners. Okada et al (2006) reported that hatch corners used to be assessed by combining the component induced by hull girder vertical bending and the component induced by hull girder torsion. In the design of new generation container ships, the effect of cross deck fore-aft deflection also became prominent. Iijima et al (2004) proposed a rational and practical method for torsional strength assessment of container ship structures. In order to estimate the combined stress response of hull girder as accurately as possible, the superposition method of warping stress, vertical bending stress and horizontal bending stress was also discussed.

There have been a lot of papers which discuss the importance of...