Structural Reliability Analysis for the Assessment of Ultimate Limit State of Ship’s Hull

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ABSTRACT

The aim of the present paper is to establish a procedure of Structural Reliability Analysis (SRA) for the assessment of Ultimate Limit State (ULS) of ship’s hull. A refined probabilistic models of both load (Wave-induced bending moment) and capacity (hull girder ultimate strength) have been derived by using direct calculation methods based on the latest analyzing techniques. An implemental procedure of SRA for estimating the ULS of typical merchant ships has been proposed. As application examples, a series of SRA by using First Order Reliability Method (FORM) has been performed and the annual failure probability of tanker, bulk carrier and container carrier for hull girder ULS has been calculated.

It is found from the SRA results that the most dominant condition of tanker (VLCC) is full loading and sagging condition and the other conditions seem to be negligible. In case of large bulk carrier, hogging condition is also important because of the local load effect by sea and cargo pressures together with sagging condition. Contrary to the previous two cases, full loading and hogging condition is much influential in large container carrier. Based on the obtained failure probabilities of the applied ships, a reference value of the target failure probability for ULS assessment by using SRA has been mentioned.

KEY WORDS: Structural reliability analysis, Ultimate limit state, First order reliability method, Wave-induced bending moment, Hull girder ultimate strength, Annual failure probability

INTRODUCTION

Recently, Goal-Based new ship construction Standards (GBS) has been discussed in IMO (International Maritime Organization). Under such a situation, IACS (International Association of Classification Society) will also come to consider the development of a set of more refined Rule formulation based on GBS by using structural reliability analysis (SRA) in future. The aim of the present paper is to establish a procedure of SRA for the limit state assessment of ship’s hull.

Regarding the limit states to be considered for the assessment of ship structural safety, there are four important limit states for ship structural safety, namely, Serviceability Limit State (SLS), Ultimate Limit State (ULS), Fatigue Limit State (FLS) and Accidental Limit State (ALS).

Among these limit states, the hull girder ULS is the most critical failure mode, since the collapse of ship’s hull will directly link to the loss of human lives and properties, and also to the significant marine pollution due to oil spilling. In this regard, this paper presents the procedure of SRA for the assessment of hull girder ULS of ship’s hull using latest analysis technologies.

Until now, many researches on structural reliability analysis for hull girder ultimate limit state assessment have been carried out. In these researches, the probabilistic models of both load and capacity for SRA have been derived by using practical simplified analysis or closed formulae (SSC 1990, ISSC 1991 & 2000). This is because the application of direct calculation method needs much computing cost. However, due to recent rapid progress of both computer hardware (CPU) and software (analysis technologies), the application of direct calculation method becomes practically feasible in some extents (Ostvold T.K., Steen E., Holtmark G., Fujikubo M., Pei Z.Y. 2005, Harada M. 2005).

In this paper, by using latest analysis technologies refined SRA for the ULS assessment of ship’s hull has been performed. Regarding probabilistic load model, namely, wave-induced bending moment, the response of ship motion in regular wave has been obtained by using series analysis by strip method and long-term prediction has been carried out based on long-term statistics of wave data and the probabilistic model of extreme wave-induced bending moment has been derived. On capacity model, namely, hull girder ultimate strength, series calculation by using non-linear FEA with one transverse framing model for ship cross section has been performed systematically changing dominant parameters on hull girder ultimate strength and derived more accurate probabilistic model of hull girder ultimate strength. Further, the model uncertainties (difference between estimated values and true values) of both load and capacity estimations have been considered in the models and a refined ULS format for SRA has been proposed.

Series SRA have been performed by using First Order Reliability Method (FORM) and annual failure probability for the ULS assessment of ship’s hull has been obtained. Based on the SRA results, the reliability level of some existing ships for ULS has been clarified and allowable criteria for determination of the target failure probability for future Safety Level Approach (SLA) in GBS has been mentioned.