Study on a Load History Generation Method based on “Storm Model” for Fatigue Assessment of Ship Structural Members

Fredhi Agung Prasetyo*, Naoki Osawa*, Shinnosuke Tsutumi**, Kei Shigeta*, Junji Sawamura*

*Dept. Naval Architecture & Ocean Engineering, Division of Global Architecture, Graduate School of Engineering, Osaka University
Suita, Osaka, Japan

**Yokosuka Shipyard, Sumitomo Heavy Industries Marine & Engineering Co., Ltd.
Yokosuka, Kanagawa, Japan

ABSTRACT

A methodology for crack propagation analysis which takes into account the change in sea area and season has been proposed. A technique for configuring ‘storms’ without trial and error is developed in order to configure ‘storms’ for numerous sea areas and seasons in a short period of time. The fatigue crack propagation life of a weld of a bottom longitudinal of an AFRAMAX TANKER is examined using the developed techniques. In this study, the validity of the developed techniques is demonstrated that the calculated propagation life gives acceptable estimation with the measured one. The effect of the changes in sea area and season on the fatigue life is discussed.

KEY WORDS:  fatigue assessment; storm model; wave statistics; wave-induced load; crack propagation

INTRODUCTION

At the present rules of major classification societies, fatigue assessment is one of mandatory assessments. Fatigue load throughout ship life affects the fatigue crack propagation behavior. In the conventional studies, the time history of wave induced load was modeled as time-individual random waveforms. It is known that the fatigue crack propagation rate changes with the load sequence, but this effect cannot be taken into account in this approach. Tomita et al (1995) proposed ‘storm model’ in order to take into account the load sequence effect. This model simulates wave induced stress histories at rough sea conditions, and it is configured by crescendo-decrescendo amplitude loading blocks.

Tomita’s “storm model” was derived from the long term distribution of individual wave height. This model cannot take into account the relation between significant wave height and mean wave period, and it is not consistent with theory of ship motion analysis. Kawabe et al (2004) proposed a modified “storm model”. Kawabe’s “storm model” was derived from wave scatter diagrams (e.g., GWS data), and it overcomes the drawbacks of Tomita’s model. However, it is difficult to determine the configuration (changing nature of significant wave height) of ‘storms’ because these configurations are determined by trial and error. In Tomita’s and Kawabe’s “storm models”, configurations of storms were determined from a single averaged wave scatter diagram. Wave statistics depends on sea area and season. The effect of the change in area and season on the crack propagation behavior was neglected in these models.

Osawa et al (2006) proposed a construction method of ‘storms’ with consideration of sea area and season. This method can reflected quick slow crack propagation while changing of sea areas and seasons, but fatigue life derived from this method still far from Tomita’s “storm model” where this is indicate the imperfection of ‘storms’ configuration at the wave induced load history. It is desirable to develop crack propagation analysis method with consideration of the change in sea area and season which gives acceptable fatigue life estimation and a short period of time for configuring ‘storms’.

In this study, a methodology for crack propagation analysis which takes into account the change in sea area and season is proposed. Then, in order to make improvement for the current “storm models” configuration and configure ‘storms’ for numerous sea areas and seasons in a short period of time, a technique for configuring ‘storms’ without trial and error is developed. A weld of a bottom longitudinal of an AFRAMAX TANKER is chosen as target for demonstrated the developed techniques. The validity of the developed techniques is demonstrated comparing fatigue life derives from propagation analysis, S-N assessment and the measured one.

GENERATION OF LOAD HISTORY

Wave scatter data

Configurations of storm are generated from GWS data rounded by 1/1000 in this study. This data is converted to double-permillage by fitting with the model of the conditional log-normal distribution of two variable data; the mean periods of wave ($T_w$) and the significant wave height ($H_w$), proposed by Wan and Shinkai (1995). In this model, the conditional probability of $T_w$ given $H_w$, $P(T_w|H_w)$ is given by Eq. (1) to (3). It is assumed that the marginal probability distribution of $H_w$ follows Weibull distribution. Using these fitted data, we can obtain a