Fatigue Strength Assessment of Typical Spots in Wave-Piercing Catamaran (WPC) Based on Spectral Method

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ABSTRACT

Based on Miner’s rule of linear damage accumulation and S-N curves, the fatigue strength assessment of wave-piercing catamaran(WPC) is predicated by employing the spectral-based analysis. Firstly, a finite element model of the ship structure was built. Then, the principal stress transfer functions of hotspots were calculated at different wave frequencies in several wave headings. The wave scatter diagram of the North Atlantic was used as wave loading spectrum. The fatigue strength assessment of the hotspots was conducted by using two types of S-N curves (curve II and curve III) which were recommended by DNV rules. The results show that several hotspots could not meet the service demand and must be improved. The assessment result is helpful for the structural design of the joints of similar wave-piercing catamaran(WPC) design and development.

KEY WORDS: Wave-piercing catamaran(WPC); spectral-based analysis; hotspot stress; fatigue strength assessment

INTRODUCTION

The demand for wave piercing catamarans has developed strongly over the past two decades for their superior performance in commercial and military applications since Australian company INCAT developed the first test-craft of wave-piercing catamaran in 1984. In sea state, wave piercing catamarans experience periodical wave load, thus, the hull structure will be frequently under the alternating stress. Due to its unique configuration, the integral rigidity of the hull is weaker than conventional marine structure and the problem of fatigue strength is more prominent. Therefore, fatigue strength assessment of wave-piercing catamaran is vital for ensuring the safety of the operation of ship and ship maintenance.

Currently the fatigue strength of a ship or offshore structure is generally assessed by using simplified analysis method or direct computing method. The direct computing method includes spectral method and design wave method. Liu conducted fatigue assessment of longitudinal nodes of a high-speed wave-piercing catamaran using simplified method. Xu investigated the fatigue strength of a small water-plane catamaran with CCS (China Classification Society) and DNV (DET NORSKE VERITAS) rules, respectively. The difficulties and differences on the fatigue strength calculation were discussed in detail and some improvement suggestions were proposed. Zheng investigated the fatigue strength assessment methods of small water-plane area twin-hull ship. A oil field traffic SWATH was taken as a example to discuss the effect of some parameters on the fatigue assessment, such as hotspots location, fatigue load and stress range, etc. Fuat carried out the fatigue assessment of a semi-swath type coast guard boat produced by using AA5059 H321 alloy based on the spectral approach. The result reveals that the fatigue life assessment is strongly depend on the parameters of sea region, specific wave characteristics and etc. Tran investigates the fatigue damage of a double hull tanker structural detail accounting for corrosion wastage over time. The effect on the time-dependent cumulative fatigue damage as a function of corrosion deterioration is calculated.

Based on Miner’s rule of linear damage accumulation and S-N curves, this paper focuses on fatigue strength assessment of a wave-piercing catamaran, employing the spectral-based approach. The analysis results could provide a reference for the same type wave-piercing catamarans’ structural design and maintenance.

SPECTRAL METHOD FOR FATIGUE STRENGTH ASSESSMENT

Spectral method is one of direct calculation method for structural fatigue strength assessment, which is the most reasonable and reliable approach among several methods of fatigue strength assessment. Spectral fatigue analysis can be generalized as follows:

1) The motion response and hydrodynamic pressure are derived by using wave load calculation program.
2) The wave loads were transferred to the finite element model and the finite element analysis was conducted to derive stress response of the fatigue hotspots.
3) The long term distribution of the stress range is obtained under some sea state with certain load condition, heading and wave frequency, in which sea state is specified by a wave scatter diagram.
4) The appropriate S-N curves are selected to analyze and calculate the cumulative fatigue damage of fatigue hotspots on the basic of linear accumulated. Then the fatigue life could be assessed.

The procedure of spectral analysis for fatigue assessment is showed in Fig. 1.