The Distribution of the Ice-induced Fatigue Damage for Ice Zone Platform Based on Time Domain Analysis

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ABSTRACT

At present, the method of precisely evaluating the ice-induced fatigue life for ice zone platform is not well developed. Compared with the frequency domain methods, due to adoption of the numerical simulation of ocean environmental loads and the non-linear dynamic time-history analysis of offshore platform structure, the accuracy of time domain method is high during the analysis of ice-induced fatigue. However, its application in the fatigue life analysis of the ice zone platform is limited by the huge workloads.

In order to study distribution law of platform structure fatigue damage influenced by each condition of ice load, fine-resolution three dimensional finite element modeling method of complicated tubular joints is employed and coupling model of offshore platform global and local structure is established. Finally, fatigue damage of time domain nonlinear dynamic response of 680 fatigue conditions on some platform in China’s Bohai Sea is analyzed with consideration of ice load cycle divided by natural frequency of platform structure. The result demonstrates that the whole law for the working condition distribution of the ice-induced fatigue in China’s Bohai Sea is distinct; the main damage load domain is like an oblique ellipse which is centered in the ice velocity of 34 cm/s -42 cm/s and the ice thickness of 27 cm -30 cm; the influence on the structure’s fatigue damage decreases with the increase of the distance. The influence of relationship between ice-breaking period and structure natural period on the fatigue damage is distinct. In working condition area where these two periods are close, the ice-induced resonance is appeared, and the structure’s fatigue damage is greater than other non-resonance conditions of the adjacent areas. The reasonable and efficient division of ice-induced fatigue condition within time domain fatigue life for ice zone platform can benefit from study results.

KEY WORDS: time-domain analysis; ice load; offshore platform; fine-resolution modeling; ice-induced fatigue; fatigue damage.

INTRODUCTION

In China’s Bohai Sea and northern part of Yellow Sea, sea ice has appeared every year, which has posed a serious threat on marine structures, production and life (CNOOC, 2002). The complex interaction between sea ice and structures, the number of relevant constraints and the shortage of research on ice-induced structure damage mechanism have, together, limited further development of ice zone offshore platform’s fatigue reliability study.

Time-domain and frequency-domain methods are used to analyze ice-induced fatigue on offshore platform. In time-domain method, dynamic ice force load process is simulated by using numerical method, fatigue stress response curves are obtained through the structure non-linear dynamic time-history analysis, stress cycle amplitude statistics is calculated by adopting rain-flow counting statistics. In frequency-domain method, it is assumed that the ice loads follows an ergodic and stationary normal process, dynamic analysis is carried out by use of ice force spectrum in the frequency domain in order to get structure effective stress extent. In contrast, in time-domain, although the structure fatigue stress response time-curves can be obtained with high accuracy, the computational complexity is rather considerable; in frequency-domain method, complicated numerical simulation and dynamic analysis are avoided and computational workload is reduced significantly, however the accuracy is compromised. Even though ice-induced fatigue analysis for offshore platform in the frequency domain is more attractive, in order to precisely describe marine platforms’ ice-induced damage law in ice zone, especially the aging platform structural damage law, it is necessary to make a further study for ice-induced fatigue in the time-domain.

In this paper, offshore platforms fatigue life under ice-induced loads is studied by time-domain method. According to on-site survey soil data, the structural-pile-soil non-linear model is established; fine-resolution finite element model of 28 platform tube nodes is established by coordinate mapping method; boundary conditions, displacement of whole structure and local structure is ensured consistent by using a whole-local coupling technique. According to ice condition in corresponding ice zone, the law of platform structure damage caused by 680 kinds of ice-induced sub-conditions is calculated. The study results in this paper can provide an effective reference for condition division of ice zone platform fatigue analysis.

THE NON-LINEAR MODEL OF WHOLE STRUCTURE