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Reliability Analysis of Fatigue Damage Accumulation Under Variable Amplitude Loading

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ABSTRACT

At first, Wirsching's model, which is widely employed in fatigue reliability analysis of marine and offshore structures, is analysed systematically. And it is found that Wirsching's model can be modified in several aspects. Secondly, by using statistical Miner's rule, a modified Wirsching's model is proposed. Thirdly and more importantly, based on Two-dimensional Probabilistic Miner's Rule, a new model is established for fatigue reliability analysis of structural components subjected to specified cyclic loading of variable amplitude or stochastic time history. In the end, an example is presented, from which it will be seen that this new model is very convenient and feasible in engineering application.

KEY WORDS: Variable amplitude, Stochastic loading time history, Fatigue reliability, Two-dimensional Probabilistic Miner's Rule, Wirsching's Model

INTRODUCTION

Fatigue is one of the most serious failure modes of marine and offshore structures subjected to oscillatory environmental loads. There are two major sources of uncertainty in fatigue failure of structures, one is the stochastic nature of fatigue loading time-history, the other is the random variability of material resistance to fatigue loading. Therefore, it is necessary to develop a probabilistic-statistical theory of fatigue reliability in the analysis and design of engineering structures.

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Generally, structural fatigue reliability theory consists of three parts: (1) the cycle counting technology of fatigue loading; (2) the reliability analysis of fatigue life and fatigue strength under constant amplitude loading; (3) the reliability analysis of fatigue life and fatigue strength under oscillatory loading of variable amplitude or stochastic time-history. Among those three parts above, the most key and tricky problem is how to establish the random fatigue accumulative damage rule. Since only after a reasonably random fatigue accumulative damage rule has been established, does it become possible, in terms of constant amplitude experimental results, to perform the reliability-based analysis and design of structural components subjected to cyclic loading of variable amplitude or stochastic time-history.

At present, Wirsching's model (Wirsching, 1980 and 1984, Wirsching and Haugen, 1973, Wirsching and Light, 1980, Martindale and Stahl, 1985, Knapp, 1985, Kumar and Kasan, 1990) concerning random fatigue damage accumulation is widely applied in marine and offshore engineering. In this paper, first, Wirsching's model is systematically reanalyzed; second, based on statistical Miner's rule (Shimokawa and Tanaka, 1980), a modified Wirsching's model is presented; third, based on two-dimensional probabilistic Miner's rule (Ni, 1994, Ni and Gao, 1996b), a new model is established of structural component subjected to a specified fatigue loading spectrum; in the end, an application example shows that this new model is particularly relevant to predict fatigue life of structural components subjected to variable amplitude loading.

In the following, N_c denotes fatigue life under constant amplitude loading, N_v denotes fatigue life under variable amplitude or stochastic time-history loading, and N denotes the number of cycles of fatigue loading in any form.