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Spectral and Cycle-Counting Fatigue Damage Estimation Methods for Steel Catenary Risers

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ABSTRACT

Estimating fatigue damage under wind-driven sea loading is of primary importance in the design of steel catenary risers (SCRs) serving floating hosts. For design, the wind-driven sea is modeled as a stationary random process. The resulting dynamic stress in the SCR is also a stationary random process. Spectral methods provide closed-form fatigue damage estimates in terms of statistics for stationary random stress processes. Rainflow cycle counting provides an alternative damage estimation approach that is generally applicable and requires simulation of stress time series. The rainflow approach requires more computation than spectral methods. Damage estimates using the rainflow method may be lower than spectral damage estimates; however, a substantial amount of simulation may be required to quantify the difference.

This paper considers fatigue damage in SCRs attached to both tension-leg platform and semi-submersible hosts. Spectral and cycle-counting estimates are generated and compared. Accuracy of the estimates is discussed, and guidelines for damage estimation are presented. It is demonstrated that the differences between spectral and cycle-counting estimates of lifetime fatigue damage arise primarily from assumptions made regarding the spectral shape of the stress processes of interest.

INTRODUCTION

SCRs accommodate floating host motions through self-flexure. Since host motions persist over the lifetime of the SCR, the task of estimating fatigue damage under wind-driven sea loading is of primary importance in the design of SCRs serving floating hosts. This paper investigates three basic approaches to this task:

1. Spectral damage estimation using results of frequency-domain analysis (Rayleigh and bimodal)
2. Rainflow cycle counting of stress time histories obtained from time-domain analysis
3. Rainflow cycle counting of stress time histories created from frequency-domain analysis results

Cycle-counting techniques require the simulation of stress time histories. The accuracy of the resulting fatigue damage estimates depends on the amount (and accuracy) of simulation. Practical computational efficiency considerations have led to the development of spectral methods that match cycle-counting damage estimates for certain forms of stress spectra. Spectral fatigue damage estimation procedures represent powerful and efficient tools for estimating fatigue damage caused by stationary random stress processes because they relate fatigue damage to the statistics of the stress process using a closed-form relationship and do not require creation of stress time histories. The spectral approach will overestimate damage (relative to cycle-counting estimates) when the spectral shape of the process is more broad-banded than the form assumed in developing the spectral procedure.