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Mean stress effect correction in frequency-domain methods for fatigue life assessment

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Abstract

Two fatigue life calculation methods are presented. One defined in the time domain and the second one defined in the frequency domain – both supplemented with a mean stress effect correction. The method is verified on the basis of own results for the S355JR steel. The authors analyze six models for the designation of the probability density function (PDF) of stress amplitudes used in the calculation process. The results are presented in the form of probability distributions before and after PSD transformation and the calculated fatigue life's are being compared with the experimental ones in fatigue comparison graphs.

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*Keywords:*mean stress, spectral method, random loading, PSD, fatigue;

1. Introduction

The phenomenon of material fatigue, which occurs due to the impact of time varying forces is one of the main reasons for material failure. The variable forces which are the main reason for this effect can be divided into two groups with constant amplitude loading and random loading. Those loads can be described with the use of deterministic formulas or with the use of stochastic theory [1]. The mean stress effect in fatigue life assessment is a well-known issue discussed widely in the literature. The mean stress is an extra static load in the form of an additional load applied to the construction or its self-weight [2]. Engineers have to take into account those kind of extra loads and prevent early fatigue failure or other construction defects. Although the literature presents solutions for the correction of mean

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stress in the time domain (cycle counting methods), it is rare to find a solution in the frequency domain (spectral method) [3]. The authors have presented a mean stress correction method that can be used in the frequency domain. For this cause a power spectral density transformation is used [4]. The transformation process is realized with the use of well-known mean stress compensation models. The fatigue life is being calculated with the use of probability density functions as well as damage accumulation hypothesis. The presented correction method is verified with own test results for the S355JR steel for narrowband and broadband loading characteristics. The method is being compared with the method proposed by Kihl and Sarkani [5]. The proposed calculation procedure can be used for narrowband as well as for broadband loading characteristics, independently from the spectral method for determination of the probability density function (PDF) of amplitudes.

Nomenclature

$K(\sigma_m)$	mean stress compensation coefficient,
$G_\sigma(f)$	power spectral density of a centered stress course,
σ_a	stress amplitude,
σ_m	mean stress,
σ_{max}	maximum stress,
σ_{min}	minimum stress,
σ'_f	fatigue strength coefficient,
$\Delta\sigma$	stress range,
$p(\sigma_a)$	stress amplitude probability density function,
R	stress ratio,
R_m	tensile strength,
T_{cal}	calculated fatigue life,
T_{exp}	experimental fatigue life.

The mean stress value used in the process of fatigue life assessment is presented as the static component of the stress history according to the formula:

$$\sigma_m = \lim_{T\to\infty}\frac{1}{T}\int_0^T \sigma(t)dt\,. \tag{1}$$

For the constant amplitude loading the mean stress value is defined as the algebraic mean of the maximum and minimum stress value in one cycle. When discussing the mean stress value we refer to some basic formulas:

- Stress range

$$\Delta\sigma=\sigma_{\max}-\sigma_{\min}\,, \tag{2}$$

where σ_{max} and σ_{min} are respectively maximum and minimum stress.

- Stress amplitude

$$\sigma_a = \frac{\sigma_{\max}-\sigma_{\min}}{2}\,. \tag{3}$$

- Mean stress

$$\sigma_m = \frac{\sigma_{\max}+\sigma_{\min}}{2}\,. \tag{4}$$