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Probabilistic S-N curves for constant and variable amplitude

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Abstract

Welded details in steel bridges are subjected to fatigue lives up to $200 \cdot 10^6$ cycles due to traffic loads. While the majority of these stress ranges are below the Constant Amplitude Fatigue Limit (CAFL), some few high stress cycles can trigger the start of fatigue damage and lead the remaining load spectra to become damaging. The behaviour under spectra loading is thus of major importance for the fatigue design of steel bridges. This paper focuses on the fatigue behaviour of welded joints under variable amplitude loads. Fatigue tests have been conducted under constant and variable amplitudes on a typical bridge detail. Experimental crack growth curves were obtained using the Alternative Current Potential Drop method (ACPD), which showed the detrimental effect of stress ranges below the conventional CAFL. A two-step model with initiation-propagation was established to estimate the experimental fatigue lives, using a local strain approach for the initiation life and fracture mechanics for crack propagation. The model was implemented in a probabilistic Monte Carlo framework to include variability on the main parameters and establish S-N curves for Constant and Variable amplitude. The results of the simulations show that load spectra shape can be correlated with the S-N curves, namely the 2^{nd} slope value below the CAFL.

Keywords:
Fatigue tests, Flange tip attachments, Fracture mechanics, Initiation-propagation model, Double slope S-N curve

1. Introduction

Modern bridge construction in the last decades, has highlighted the importance of steel solutions for the design of bridges (Reis, 2008). Steel bridges have become slender and lighter with the generalisation of welded connections, increasing the relevance of fatigue phenomena and, as a result, fatigue design has become a leading ultimate limit state verification (Nussbaumer and Schumacher, 2002).

Stress amplitudes due to traffic loads are high and may further be amplified by dynamic effects. Fatigue and dynamic behaviour have thus become intrinsic to the concept design since both are highly dependent on the choice of structural solutions (de Goyet et al., 1999).

Under variable amplitude load spectra, both highway and railway bridges are subjected to occasional overloads and stress peaks, followed by millions of cycles at low amplitudes (Fisher et al., 1993). The damage process due to stress ranges below the CAFL, depends on the load spectra, and design provisions based on a double slope S-N curve have shown to be unsafe under some conditions (Gurney, 2006).

Variable amplitude fatigue tests in very high cycle regime ($N > 10 \cdot 10^6$ cycles) are thus fundamental to estimate fatigue life under service loads. The experimental data in this range is however very limited, because they are expensive and time consuming. Few results have been obtained in relevant bridge details under constant amplitude beyond $5 \cdot 10^6$ cycles, even less can be found under variable amplitude for lives above $10 \cdot 10^6$ cycles. This paper presents experimental results up to $70 \cdot 10^6$ cycles, both under constant and variable amplitude. The damaging character of stress cycles with amplitudes below the CAFL was investigated with experimental crack growth curves, obtained using the Alternative Current Potential

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