Influence of inspection on the safety of fatigue loaded welded cruciform steel joints – comparison of simplified and advanced crack growth models

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Abstract

Probabilistic fatigue life prediction models of welded steel joints are often used to estimate the level of safety, which is given in terms of the probability of failure or the reliability index as a function of the applied load cycles. Prediction models based on fracture mechanics allow taking into account the effect of inspections on the estimated level of safety. Recent developments in fracture mechanics based fatigue prediction models allow modeling the behavior of short and long fatigue cracks under constant and variable amplitude loading. Short cracks are relevant since their growth characterizes most of the fatigue life, especially under service loading. A recently proposed model by the authors is considered and compared to a more traditional and simplified model as proposed in the standard BS7910, where no distinction is made between short and long cracks. The effect of the model uncertainty, the type of inspection, and the time of the inspection on the estimated level of safety are quantified for welded cruciform steel joints.

Keywords: Welded stiffeners; Fracture mechanics; Fatigue inspection; Structural reliability

1 Introduction

The fatigue life of as-welded connections is dominated by fatigue crack propagation, therefore, Fracture Mechanics (FM) is capable of estimating the fatigue life of such connections. However, the large number of model parameters involved, and the difficulties related to estimating the local geometry parameters make its use complex [1], and its outcome subjected to large uncertainty when compared to nominal S-N curves. By performing regular inspections aimed to detect fatigue cracks it is possible to reduce the uncertainty [2] related to the safe use of the structure, where the safety can be estimated using the FM model. FM is used to assess the safety of bridge infrastructures with the aim of extending their life or planning inspections. Moreover, the service loading for bridge infrastructures is of variable amplitude (VA) type, which determines non-linear load sequence effects of which sound modeling for universal application is missing [3].

Past studies from Schilling and Klippstein [4] aimed to determine the type of stress spectrum resulting from the traffic loading of short-span bridges. These studies indicated that a statistical description of the stress history is sufficiently accurate when the stress spectrum is assumed to follow a Rayleigh distribution truncated at a maximum stress range $\Delta\sigma_{max}$, and having scale parameter equal to one:

$$f(z) = z\, e^{-0.5\, z^2} \tag{1}$$

where z is the normalized stress range, ranging between 0 and $z_{max} = 3$, the stress range is obtained as $\Delta\sigma = \Delta\sigma_{min} + z\,\Delta\sigma_d$, $\Delta\sigma_{min}$ is the minimum stress range of the spectrum, and $\Delta\sigma_d =$

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