Probabilistic Model for Fatigue Crack Growth in Welded Bridge Details

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Summary

In the present paper a probabilistic model for fatigue crack growth in welded steel details in road bridges is presented. The probabilistic model takes the influence of bending stresses in the joints into account. The bending stresses can either be introduced by e.g. misalignment or redistribution of stresses in the structure. The fatigue stress ranges are estimated from traffic measurements and a generic bridge model. Based on the probabilistic models for the resistance and load the reliability is estimated for a typical welded steel detail. The results show that large misalignments in the joints can have a significant influence on the reliability level.

Keywords: Fracture mechanics, Reliability, Steel, Welded details, Traffic load, Fatigue.

1. Fatigue crack growth

The fatigue crack growth in a welded steel detail is modelled using linear elastic fracture mechanics and a two dimensional semi-elliptical surface crack. The crack growth rate is estimated using the Paris law. For road bridges a large number of small to medium size stress cycles are often observed for which reason a bilinear version of the Paris law is used, in order to obtain a good accuracy for these stress cycles. The stress intensity factors for the welded detail take the influence of bending stresses and misalignment in the detail into account.

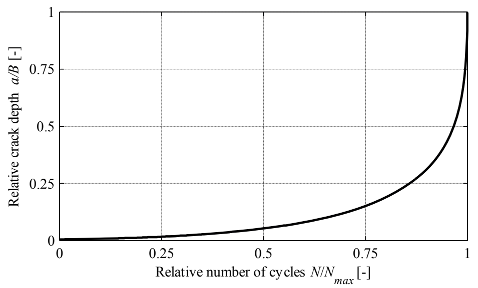

Figure 1: Typical development of fatigue crack

In the probabilistic modelling the initial crack size from small flaws in the welding process has a significant influence on the development of the fatigue crack. Additionally, the uncertainty related to the stress intensity factor and stress concentrations in the detail has a significant influence. The typical development of a fatigue crack with the number of cycles is shown in figure 1.

2. Fatigue stresses

The distribution of the membrane fatigue stresses is estimated from measured weigh in motion (WIM) data and a generic bridge model. The distribution of the gross vehicle weight (GVW) is

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shown in figure 2 (left), where a bimodal tendency is observed with a peak around both 150 kN and 350 kN. In order to transform the measured loads into stress cycles the vehicles are passing a generic bridge with constant speed by which load time-series are obtained. In figure 2 (right) the probability density function for the stress ranges is shown. The stress ranges show a multimodal tendency (like the GVW) for which reason kernel smoothing has been applied in order to approximate the stress ranges well.

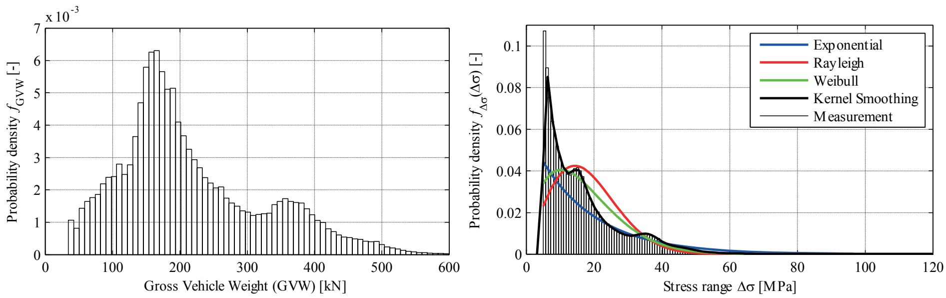

Figure 2: Left: Distribution of gross vehicle weight for WIM-data. Right: Probability density function for stress ranges

3. Reliability Assessment

The reliability of a butt-weld detail in a steel plate is assessed in order to determine the influence of bending stresses and misalignment. The butt-weld detail is designed to the limit according to Eurocode 3 using detail category 90. The SN-curve is assumed bilinear without a cut-off limit and the accumulated damage is estimated using Miners rule for linear damage accumulation. A safe-life design approach is used and the service life of the detail is assumed to be 100 years.

The accumulated reliability index dependent on time is shown in figure 3. A significant reduction of the reliability level is observed when bending stresses and misalignments are introduced in the welded detail.

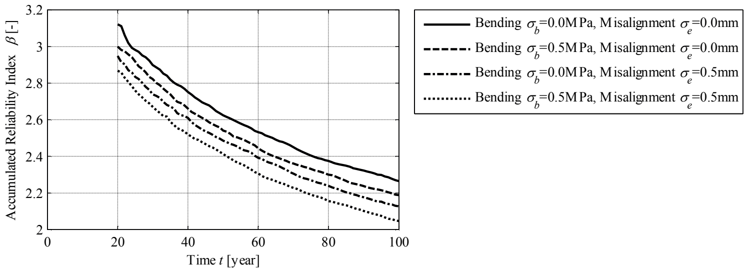

Figure 3: Time dependency of accumulated reliability index and influence of bending and misalignment

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