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Model for fracture mechanics based prediction of the fatigue strength of engineering alloys containing microscopical initial defects

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Abstract. Recently two of the authors of the present paper proposed a model for fracture mechanics based prediction of the S-N characteristics of metallic components with large microstructural defects and supported this by a validation excercise on an aluminium alloy AL5380 H321. Within this presentation the authors extend the study using a number of data sets from the literature. Despite of necessary assumptions for the compensation of partially missing input information the results are fairly reasonable, with the exception of high loading levels where the analyses of two of the data sets yield non-conservative results. The authors propose multiple crack initiation as the potential root of the problem and discuss methods for extending the model for taking into account crack initiation.

1 The basic model

In [1] two of the present authors proposed a model for the fracture mechanics based determination of the fatigue strength and life based on the assumption of a negligible short crack initiation stage. This allowed them to base the analysis on a pre-existing defect which they treated as initial crack. The scheme of the proposed model is shown in Fig. 1.

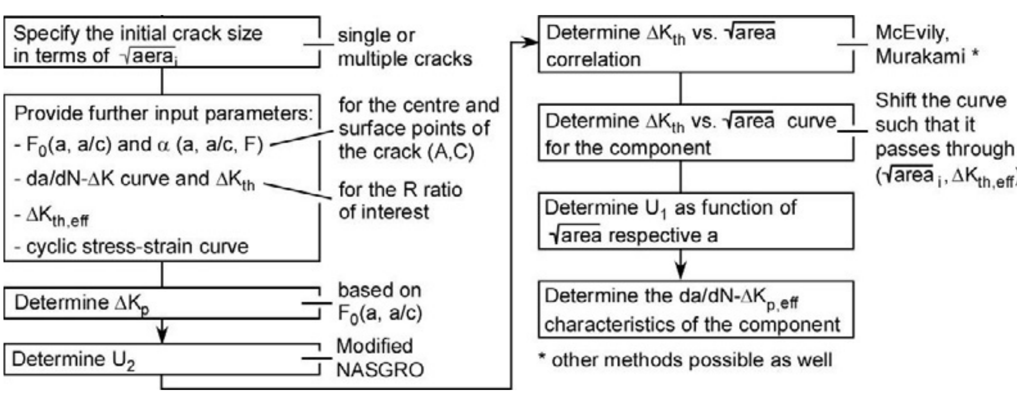

Figure 1. Input and model parameters and working steps of the fracture mechanics model proposed by the authors in [1] ($\sqrt{\text{area}}$ - crack area ; F_0 – net section reference load; α – constraint parameter).

Key points of the method are the determination of a crack driving force ΔK_p taking into account local ligament yielding and the gradual built-up of the plasticity-induced crack closure effect. The first item is realised by a proposal of McClung [2] :

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$$\Delta K_p = \sqrt{\Delta J \cdot E'} \tag{1}$$

with
$$\Delta J = \frac{\Delta K^2}{E'} \cdot \left[f\left(\Delta L_r\right)\right]^{-2}, \tag{2}$$

and
$$\Delta L_r = \frac{\Delta F}{2F_Y} = \frac{\Delta\sigma_{ref}}{2\sigma_Y}, \tag{3}$$

the second by a function
$$U_1 = \frac{U_2}{\Delta K_{th}\left(a\right)/\Delta K_{th,lc}} \tag{4}$$

with U_2 being the long-crack closure (= $\Delta K_{eff}/\Delta K$) function according to Newman [3], and U_1 being the short-crack transient closure function mirrored by the development of the fatigue crack propagation threshold ΔK_{th} with crack extension. The latter is described by an equation of McEvily et al. [4] but other descriptions are possible as well:

$$\Delta K_{th} = \Delta K_{op} + \Delta K_{th,eff} = \left[1 - e^{-k\cdot(a-a_0)}\right]\cdot \Delta K_{op,max} + \Delta K_{th,eff.} \tag{5}$$

2 Validation

Detailed information on the model and its validation is found in [5]. In the following only the two data sets are shown where the model yielded non-conservative results at high loading levels (Fig. 2) In their presentation the authors discuss the issue of multiple crack initiation depending on the loading level as the potential reason and provide proposals for treating the effect in an extended model.

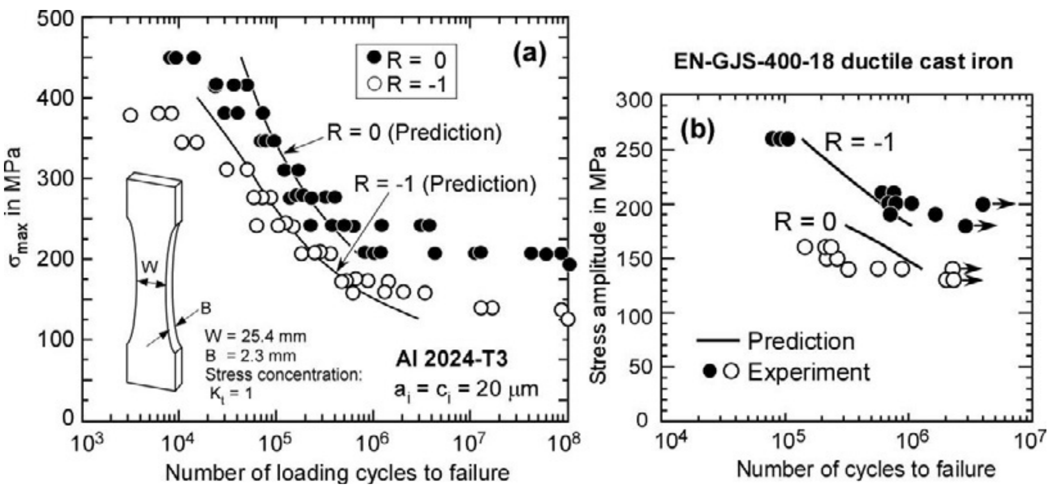

Figure 2: Model validations: (a) Al 2024-T3; (b) Ductile cast iron EN-GJS-400-18-LT. Information on the literature data sets is provided in [5].

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