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Comparison between different methods for the prediction of the fatigue limit of a member with a small crack

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Abstract

In the Kitagawa-Takahashi diagram and the corresponding analytical model by El Haddad *et al.*, the fatigue limit of a cracked member is a monotonically decreasing function of the fatigue crack size. Based on data from fatigue tests by Schönbauer on plain and cracked members of 12% Cr steel at R = -1, the present investigation shows that the Kitagawa-Takahashi-El Haddad 'short-crack' model yields predictions in good agreement with those by Frost and Murakami for different ranges of the crack size. The comparison with Frost's model is based on a surface through-crack, that with Murakami's $\sqrt{area}$ model on an embedded elliptical crack.

Keywords: Chromium steel; crack shape; defects; elliptical cracks; fatigue limit; fatigue thresholds; flaw size; plain specimens; small cracks; stress intensity factors

1. Introduction

The influence on the fatigue limit of material defects and small cracks has been extensively investigated in the past. Thus, classical works by Frost *et al.* (1974) and Kitagawa & Takahashi (1976), the latter modelled by El Haddad *et al.* (1979), treat the effect of short surface cracks on the fatigue limit. Murakami (2002) has summarised comprehensive work on the effects of small defects and non-metallic inclusions. Recent experimental and modelling work related to the influence on the fatigue limit of corrosion pits has been reported by Schönbauer (2014) and

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Härkegård (2015, 2016).

The present work is a comparison between predictions of the fatigue limit of members with small cracks according to El Haddad *et al.* (1979), on one hand, and Frost *et al.* (1974) and Murakami (2002), on the other. The modelling will be based on fatigue and hardness data from a comprehensive experimental investigation of a 12% Cr steel by Schönbauer (2014), as given by Table 1, as well as empirical equations by Frost and Murakami.

Table 1. Mechanical properties of a 12% Cr steel (AISI 410, X12Cr13), batch 'R', according to Schönbauer (2014).

Tensile strength R_m, MPa	Yield stress $R_{p0.2}$, MPa	Vickers hardness HV	Fatigue limit $\Delta\sigma_A(R=-1)$, MPa	FCG threshold $\Delta K_{th}(R=-1)$, MPa$\sqrt{m}$
767	596	250	880	6.77

2. Fatigue-limit modelling of plain members with small cracks according to El Haddad

By plotting the fatigue limit of a cracked member as shown in Fig. 1 against the crack depth, Kitagawa and Takahashi (1976) obtained a continuously decreasing curve as the one marked 'El Haddad' in Fig. 2. For sufficiently small cracks $(a << a_0)$, the fatigue limit of the cracked member approaches the plain fatigue limit, $\Delta\sigma_A$. For sufficiently large cracks $(a >> a_0)$, the fatigue limit of the cracked member is governed by the FCG threshold, ΔK_{th}. The 'intrinsic' crack size, a_0, will be defined below.

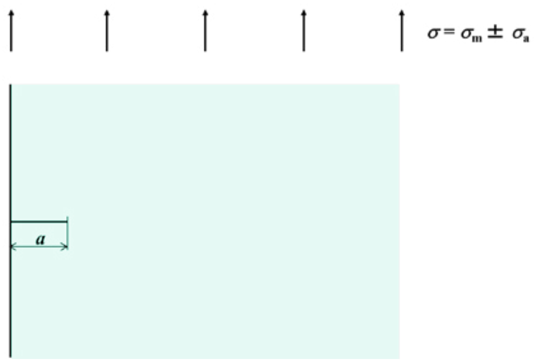

Fig. 1. Plain member with surface through-crack of depth *a* subjected to cyclic loading.

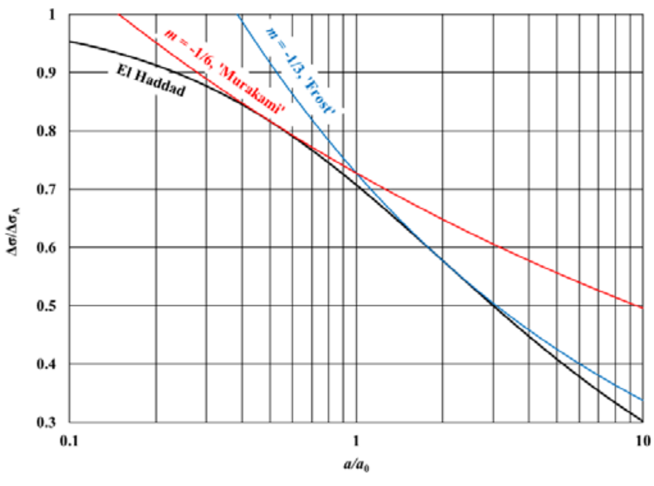

Fig. 2. Kitagawa-Takahashi diagram with El Haddad and power-law graphs.