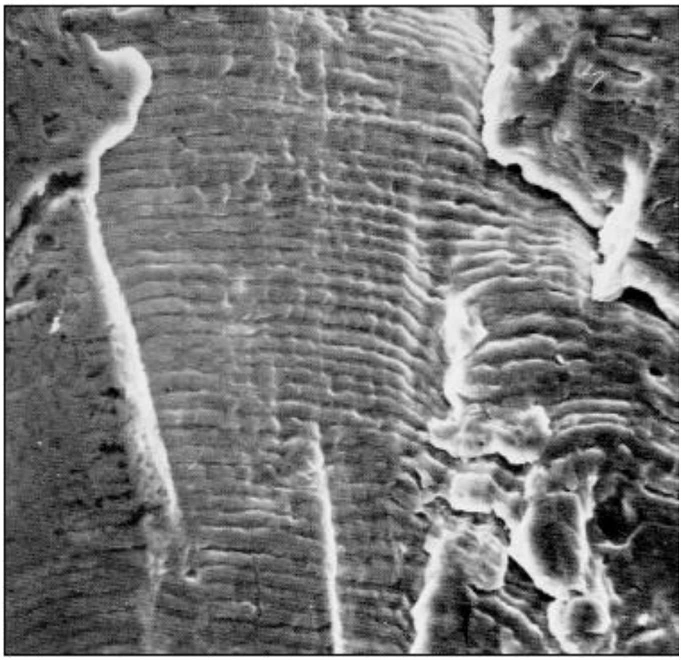
Fracture mechanics, damage and fatigue: project (MECA0058-1)

SIF computation using a finite element model & Fatigue crack propagation



Ludovic Noels

Academic year 2023-2024

1. Project

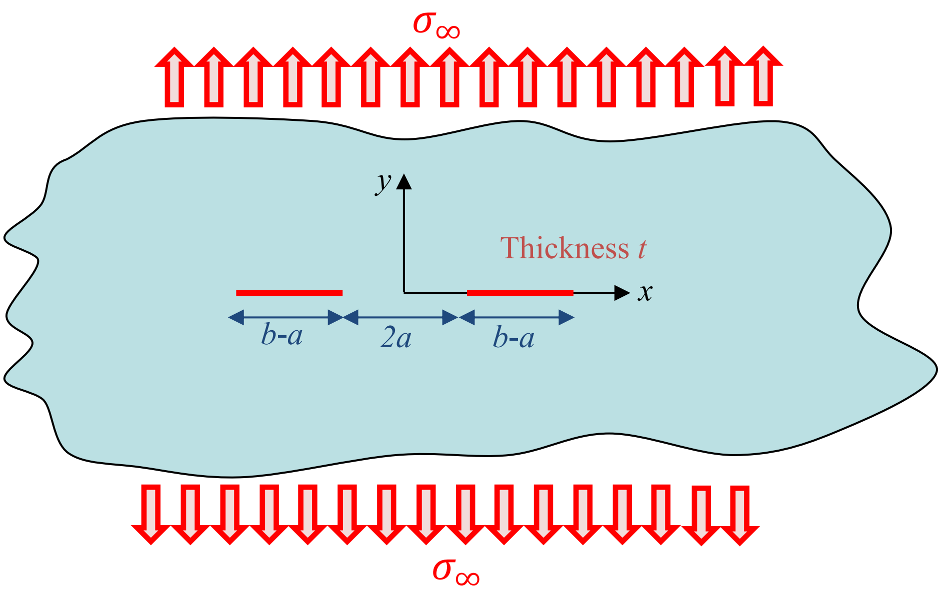


Figure 1: double cracks in an infinite plane

You are requested to study the fatigue crack propagation of a doubly-cracked infinite plate under tensile loading condition. The geometry is illustrated in Figure 1. Under the linear-elastic assumption, the stress intensity factors at the different crack tips are expressed as[1]

$$K_I|_{x=\pm a} = \sigma_\infty \sqrt{\pi a}\,\frac{\frac{b^2 E(k)}{K(k)} - a^2}{a\sqrt{b^2-a^2}},\ K_I|_{x=\pm b} = \sigma_\infty \sqrt{\pi b}\,\frac{1}{k}\left(1 - \frac{E(k)}{K(k)}\right)$$

with

1) $k = \sqrt{1 - \frac{a^2}{b^2}}$;
2) $K(k) = \int_0^{\frac{\pi}{2}} \frac{d\varphi}{\sqrt{1-k^2\sin^2\varphi}}$; $E(k) = \int_0^{\frac{\pi}{2}} \sqrt{1 - k^2\sin^2\varphi}\, d\varphi$
3) $K(k)$ and $E(k)$ are also reported in the handbook[1].

The material considered is a 7075-type aluminum alloy, with heat treatment 651 (properties in Table 1 and on Figure 2).

Table 1: Material properties (T=25° C)

Material	Young Modulus	Poisson coefficient	Toughness	Yield stress	Critical tensile strain
7075-T651 Aluminum /Zinc	72 GPa	0.33	30 MPa $m^{1/2}$	500 MPa	9%

[1] The Stress Analysis of Cracks Handbook, Third Edition By Hiroshi Tada, Paul C. Paris, George R. Irwin, 2000, ISBN-10:0791801535 No. of Pages : 698, DOI: https://doi.org/10.1115/1.801535, https://asmedigitalcollection.asme.org/ebooks/book/188/The-Stress-Analysis-of-Cracks-Handbook-Third (available on myULiege: https://my.uliege.be/portail/go_xt.do?a=o%7C3117%7Ce%7C520097)

COMPARISON OF FATIGUE CRACK GROWTH RATE DATA FOR ALLOY 7075-T651, 2024-T351 AND 7475-T651 PLATE

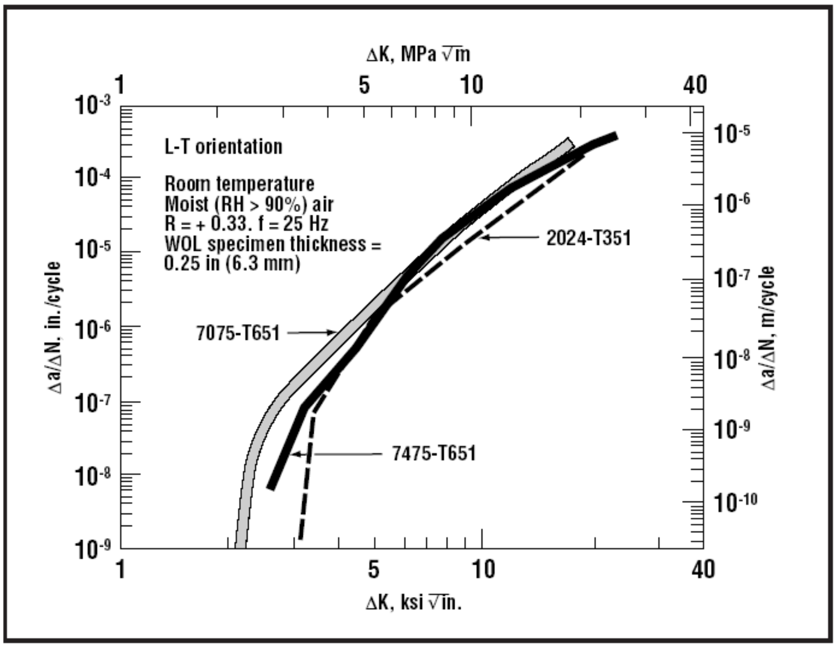


Figure 2: Courbe de fatigue pour les alliages aluminium/zinc.

A/ Comparison of the FEM method with the handbook:

Table 2: Geometry for part A/

Thickness t [m]	Initial crack front a_0 [m]	Initial crack front b_0 [m]	Maximum stress $\sigma_{\max}$ [MPa]
0.01	0.03	0.05	150

Considering the properties reported in Table 2, you are requested to determine the stress intensity factor at both crack fronts of each crack using

- The handbook;
- The finite element method, using any kind of software, and using (you may use the fracture mechanics features like the J-integral of the FE code for comparison purpose only)
    - the energetic method;
    - the stress correlation method;
    - the displacement correlation method;
- To compare the different results.

B/ Crack propagation using the handbook:

The sample described in point A/ is subjected to a constant cyclic loading with

- As maximum value, the loading in Table 2;
- As minimum value, one third of the maximal loading.

You are requested to evaluate, using the handbook,

- The evolution of the two crack front positions, of each crack, with the number of cycles;

- The life of the structure

C/ Crack propagation using the FEM:

The sample described in point A/ is subjected to a constant cyclic loading with

- As maximum value, the loading in Table 2;
- As minimum value, one third of the maximal loading.

You are requested to evaluate using the finite element code and **one of the tested methods**.

- The evolution of the two crack front positions, of each crack, with the number of cycles;
- The life of the structure

D/ Discussion:

You are also requested

- To compare and discuss the different results in part B and C
- To ascertain the validity of the different approaches;
- To discuss the validity of the results.

2. Work plan

The project will be achieved by groups of 2 students.

A report containing parts A to D will be printed and handed to Ludovic Noels before December the 18th, 2023.

The code (in any language) used for the analyses will be given in annex of the report.