Interactive Fatigue Lab

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Experimental lab report, due XX/XX/XXXX

# Getting Started

# You will need to download the free CDF player at: [https://www.wolfram.com/player/](https://urldefense.proofpoint.com/v2/url?u=https-3A__www.wolfram.com_player_&d=DwMFaQ&c=u6LDEWzohnDQ01ySGnxMzg&r=8BazBkWsu90pWeW8f9tFng&m=1LrkZCuS6bv6SMDqjIjgQEtb1O6eMN1QMmyVEdf10Ko&s=xLdrt4XPW9ub_84W5RuLCGS1dQkSHzSjM7CA--8OFOM&e=). After installation of the CDF player, open the CDF file corresponding to the fatigue lab. This CDF file will allow you to conduct virtual experiments. Please note that you need to record the data produced in these experiments since the CDF file will NOT save the data when you finish. You can right click the data and copy as plain text to paste into another application like Excel.

# Objectives

The purpose of this exercise is to understand the principle of fatigue, relate fatigue to linear elastic fracture mechanics, and apply Paris’ law to the simulated data. This will be achieved by running virtual experiments where repeated loading is applied to “break” an unknown specimen.

# Introduction

Fatigue failure occurs due to repeated loading at a stress level considerably lower than the tensile strength, yield strength, or the fracture stress (determined from linear elastic fracture mechanics) for a static load. Recall from linear elastic fracture mechanics that cracks propagate and failure occurs when the applied tensile stress is above the critical stress () where

, (1)

and  is the critical stress intensity factor for the material in question,  is a geometrical parameter, and  is the crack length in the material before applying the stress.

What happens when the tensile stress applied () is less than the critical stress? The crack length grows a little bit. If the stress is removed and reapplied? The crack grows a little bit again. If this process is repeated, eventually the crack length grows long enough such that , at which point the crack rapidly propagates and fracture occurs.

Under repetitive load cycling at a stress level below , the change in crack length per load cycle (*N* is the number of cycles) was found by Paris to be proportional to the change in stress intensity factor raised to the power *m* such that

(2)

. (3)

Here, *m* is a material specific coefficient that generally ranges between 2 and 10, and *C* is an additional coefficient that depends on the material being tested. The above relation is referred to as “Paris’ law.” With the above equation we can quantitatively predict the residual life for a crack of certain size. Please keep in mind that the crack length, *a*, in eq. (3) is a function of *N* (since it gradually increases with increasing load cycles).

# Procedure

**Task 1:** Each group will run several simulations where they obtain the crack growth with increasing load cycles, the crack length at failure, along with the number of cycles at failure. For each initial crack length and stress amplitude, they should do at least three different  step sizes. Record the change in crack length with all  steps.

Table 1: Example data table

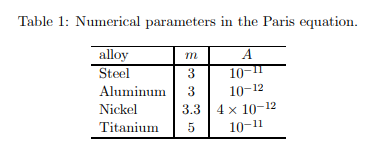
|  |  |  |  |
| --- | --- | --- | --- |
| Crack Location | Initial crack length a­0 | Stress Amplitude |  |
| Center | Two different lengths | One stress | Three different step sizes |
| Edge | Two different lengths | One stress (less than used for the center crack) | Three different step sizes |

**Task 2:** Using LEFM, calculate the maximum crack length () for each stress amplitude considered. Compare the answers to the fatigue simulation and discuss why they may be different. Use the critical stress intensity factor  as 44 MPa.

**Task 3:** For each simulated fatigue test you perform, fit Paris’ law to the simulated data to determine the coefficients *C* and *m*, and find the unknown material that was simulated based on the values of the fitted coefficients (Refer to Table 1 below). Calculate the average *C* and *m* values.

Hint: There are two ways to go about fitting Paris’ law to your simulated data in order to determine the proper *m* and *C* coefficients. In both cases, you need to solve for crack length at each load step (i.e., as a function of *N*). This process can be done numerically by approximating the derivatives in eq. (3) as ‘deltas’ or analytically by integration. You may use either technique. If you use the latter technique, you may use curve fitting algorithms to fit your analytical expression to the simulated data to get *C* and *m* (e.g., a least squares algorithm such as in *Mathematica* or *Matlab*). If you use the numerical approach, you can simply adjust the values of *m* and *C* until your modeled values of *a* visually align with the simulated experimental values at each *N*.

**Table 2: Numerical parameters in Paris’ law equation [1]**



Reporting Requirements

Use the experimental lab report format for this lab write up. In addition to meeting the requirements for a formal lab report please address the following bullet points in the discussion section of your lab report.

* For task 1, present a table with  and *N* values at failure.
* Why does the value for  change as a function of step size? Note that the simulated experiment only records up to the last measurement for *N* and *a* prior to fracture occurring.
* Discuss why  obtained from LEFM is different compared to that obtained from your fatigue simulations.
* What material was used to make the virtual specimens you tested?
* Why does a fractured surface often feel warm just after failure?
* Would the rate at which the cycles are applied affect the number of cycles at failure? What about the stress ratio (presumed here to be zero)? How might changing the *R* value to -1 affect the *C* and *m* coefficients?

**Reference**

1. [https://ocw.mit.edu/courses/materials-science-and-engineering/3-11-mechanics-of-materials-fall-1999/modules/MIT3\_11F99\_fatigue.pdf](https://urldefense.proofpoint.com/v2/url?u=https-3A__ocw.mit.edu_courses_materials-2Dscience-2Dand-2Dengineering_3-2D11-2Dmechanics-2Dof-2Dmaterials-2Dfall-2D1999_modules_MIT3-5F11F99-5Ffatigue.pdf&d=DwMFaQ&c=u6LDEWzohnDQ01ySGnxMzg&r=8BazBkWsu90pWeW8f9tFng&m=Gq_RzSRqiE-CGoBLl7DOuDnuKuoD5sbCQfZlG9C2MNI&s=oASYCOj9TGeHGxqyKkIpnwevjlnapjOHpYaI8lqqfEA&e=).