

Lecture 13 - Project Discussion

Dr. Nicholas Smith

Wichita State University, Department of Aerospace Engineering

8 March 2022

1

schedule

- 8 Mar - Stress-based Fatigue
- 10 Mar - Stress-based Fatigue, HW6 Due, HW5 Self-grade due
- 15 Mar - (Spring Break)
- 17 Mar - (Spring Break)

2

- exam
- final project
- fatigue
- nominal and local stress
- fatigue tests

exam

final project

general description

- This is in place of a final exam
- Should demonstrate your understanding of the course as a whole
- Choose any real object
- Needs to undergo some cyclic loading (for fatigue)
- Materials, loads, and any other “given” data can be made up

5

overview

- Estimate stress intensity factor at some critical location
- Estimate residual strength (use a “typical” crack length)
- Estimate fatigue life
- Estimate crack propagation
- Suggest reasonable inspection cycle for safe use
- Suggest an improvement to make part more damage tolerant

6

grade breakdown

- Per course syllabus, project will be worth 25% of final grade
- 5% Project abstract submission and approval
- 15% for each major component
 - stress intensity factor
 - residual strength
 - fatigue
 - crack propagation
 - inspection cycle

7

grade breakdown

- 10% for damage tolerant improvement
- 10% general presentation, organization, and grammar

8

project abstract

- Main purpose of abstract is for you to make sure your idea fits with project purpose
- I will give you feedback on how to tweak your proposed idea to better meet project purpose
- Abstract submission should be 1-2 pages
- Briefly describe your chosen part, how it undergoes cyclic loading, what location you intend to consider for the stress intensity factor.
- This is like a proposal: convince me that your idea has what it takes to be a great final project

9

justify assumptions

- You will need to make many assumptions in order to complete this project
- Clearly state your assumptions and justify them (i.e. if you assume plane strain conditions, justify that by showing how thick your part is)
- Although will not have experimental or FE analysis specific to your part, use concepts from other data in the text (stiffeners, multiple site damage) in a qualitative manner

10

- Figures can greatly enhance your project report, if you use them well
- Many readers will jump to figures in a report, include sufficient information in caption and axis labels so a reader with general damage tolerance understanding can understand your figure
- This will interest them in the rest of your paper

11

examples

- Last year I did not curve final project grades
- Some examples of a couple of good project reports have been posted to blackboard (and here¹)
- You should not use their projects, but they have very good use of figures, as well as an appropriate balance of both depth and breadth in the their analysis

¹<https://ndaman.github.io/damagetolerance/#/2/2>

12

fatigue

fatigue

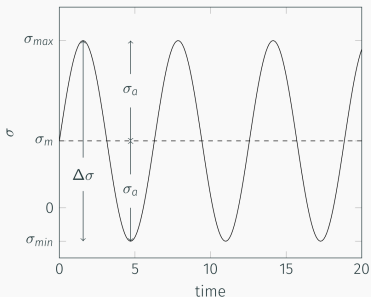
- We refer to damage from repeated, or cyclic loads as fatigue damage
- Some of the earliest work on fatigue began in the 1800's
- Chains, railway axles, etc.
- An estimated 80% of failure expenses are due to fatigue

- There are three main approaches to fatigue analysis
 - Stress based fatigue analysis
 - Strain based fatigue analysis
 - Fracture mechanics fatigue analysis

stress based fatigue

- One of the simplest assumptions we can make is that a load cycles between a constant maximum and minimum stress value
- This is a good approximation for many cases (axles, for example) and can also be easily replicated experimentally
- This is referred to as constant amplitude stressing

constant amplitude stressing



16

constant amplitude stressing

- $\Delta\sigma$ is known as the stress range, and is the difference between max and min stress
- σ_m is the mean stress, and can sometimes be zero, but this is not always the case
- σ_a is the stress amplitude, and is the variation about the mean

17

constant amplitude stressing

- We can express all of these in terms of the maximum and minimum stress

$$\Delta\sigma = \sigma_{max} - \sigma_{min}$$

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

18

constant amplitude stressing

- It is also common to describe some ratios
- The stress ratio, R is defined as

$$R = \frac{\sigma_{min}}{\sigma_{max}}$$

- And the amplitude ratio, A is defined as

$$A = \frac{\sigma_a}{\sigma_m}$$

19

- There are some useful relationships between the above equations

$$\Delta\sigma = 2\sigma_a = \sigma_{max}(1 - R)$$

$$\sigma_m = \frac{\sigma_{max}}{2}(1 + R)$$

$$R = \frac{1 - A}{1 + A}$$

$$A = \frac{1 - R}{1 + R}$$

nominal and local stress

- It is important to distinguish between the nominal (global) stress and the local stress at some point of interest
- We use σ for the stress at a point (local stress)
- We use S as the nominal (global) stress
- In simple tension, $\sigma = S$

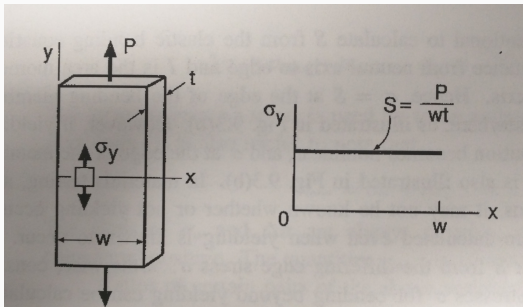
21

notation

- For many cases (bending, notches), $\sigma \neq S$ in general
- We must also be careful to note σ_y , in some cases $S < \sigma_y$ but at some locations $\sigma > \sigma_y$

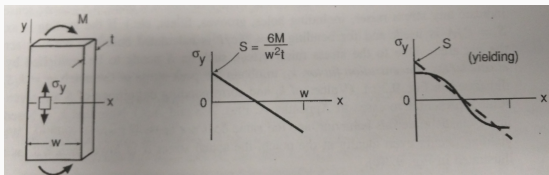
22

simple tension

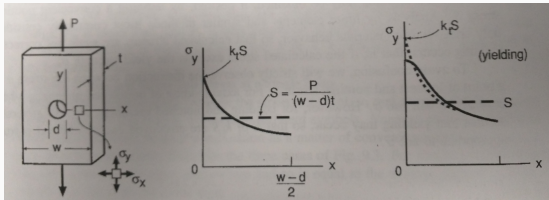


23

bending



24



fatigue tests

rotating cantilever beam

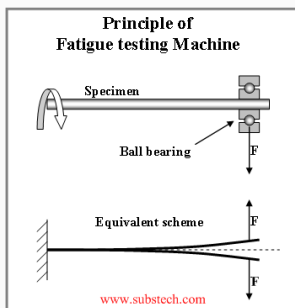


Figure 1: Stress variation through a cantilever beam

26

rotating four-point bend

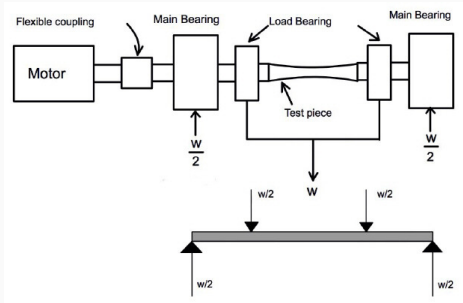


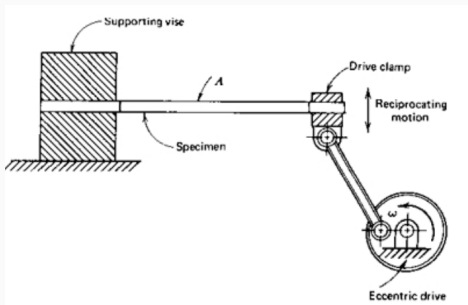
Figure 2: Four-point bend test gives uniform stress along the top and bottom surfaces

27

- The above rotating methods are very common, but in their current configurations can only be used for zero mean stress
- a reciprocating bend test can be used for non-zero mean stress

28

reciprocating bend test



29

axial fatigue test



30

fatigue tests

- The length of a fatigue test is determined by two factors
 1. How many cycles it takes for the specified load to cause failure
 2. The speed of the motor controlling the test

31

- Servohydraulic machines generally have a speed of 10 - 100 Hz.
- At a speed of 100 Hz, it would take 28 hours for 10⁷ cycles, 12 days for 10⁸ cycles, and nearly 4 months for 10⁹ cycles
- While some machines can test at very high speeds, the inertia of the sample can interfere with results