TME260 Fatigue & Fracture
Assignment 1

Stress based fatigue design – Design against rotating bending

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- Supervisor: MICHELE MAGLIO

Time to finish and hand over to supervisor **2019-09-16**

You must include **all code** in your report if you are to pass the assignment.

A flow chart for rain-flow count is included as an appendix. Further, code skeletons are available at the course home page. To follow/use these is optional, but you will not get *programming support* if they are not followed.

Background

This assignment deals with stress based fatigue design. The load is rotating bending, which is a very common load case that occurs if a rotating axle is laterally loaded and/or misaligned. In the current assignment, the rotating axle is loaded by a distributed load, see figure 1. In theory this would result in a constant amplitude alternating stress in the notch, which is located at the middle of the span, see figure 1. However due to imbalances in the machine *etc,* the stress evolution is more stochastic. To analyse the situation, axial stresses have been measured close to the mid span.

A representative nominal stress history (containing stress maxima and minima with intermediate stress levels removed) is available in the assignment folder, and is named `inputdata_XX.m` where `XX` are the two (one if below 10) last digits of your phone number.

The rotating axle is simply supported. The diameter is $d_2 = 40$ mm. In the centre of the axle there is a notch with a geometry defined by $d_1 = 38$ mm and $\rho = 6$ mm, see Figure 1.

The axle steel has a ultimate strength of $\sigma_\mathrm{u} = 800$ MPa (116 ksi). The surface is machined.

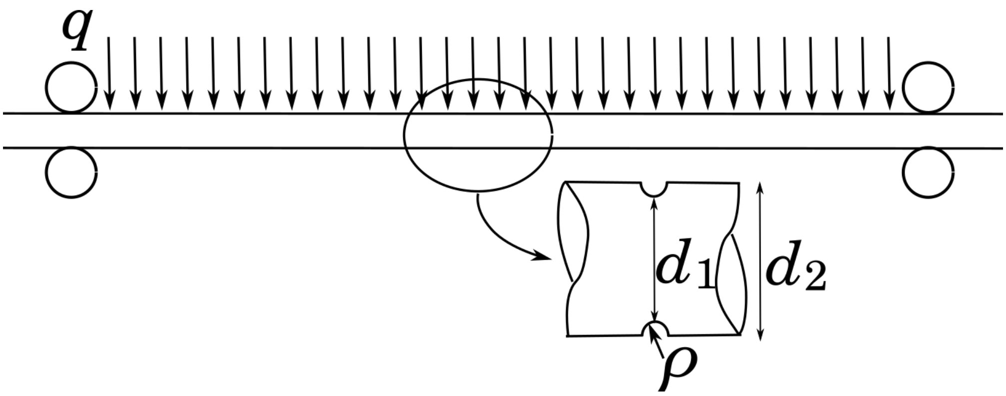

Figure 1: Axle subjected to rotating bending and loaded by a distributed load with intensity q.

Tasks

You are to analyse the fatigue life of the axle. To this end you will need to Construct an S–N-curve, evaluate (nominal) stress cycles from the measured stress data, and finally evaluate fatigue damage.

Construction of an SN-curve

The methodology is described in Dowling sections 10.4–10.7

1. Develop a fully reversed S–N-curve for the material according to Juvinal!

2. Derive the influence of the notch in terms of k_f and k_f'!

3. Construct the S–N-curve accounting for the notch!

Rainflow count

The methodology is described in Dowling section 9.9.2

4. Develop a numerical code for rainflow count analysis. Verify your code towards a simple test case (e.g. the example in the book). Employ the code to analyse the stress history you have downloaded.

- In the analysis, mid values and amplitudes for the stress cycles should be plotted (e.g. using the command `errorbar(mid,amplitude)`).
- Also plot amplitudes in a normal probability plot (e.g. using the command `normplot(amplitude)`) and comment on whether the stress amplitudes seem to be following a normal distribution.
- Finally, ensure that your code extracts the largest stress cycle.

Fatigue analysis

The methodology is described in Dowling sections 10.6.3, 10.7 and 9.9.1

5. Use the derived S–N-curve to evaluate how many load cycles the axle can sustain. Presume that the load history in the load sequence you have is representative for the loading. Note that every load sequence contains a number of load cycles. This needs to be accounted for. Your fatigue analysis should employ the SWT-criterion to account for mid stress effects.

- Make one analysis where you account for the fatigue limit (i.e. stress amplitudes below the fatigue limit are presumed not to induce any fatigue damage) and one analysis where you do not account for the fatigue limit (i.e. all stress cycles are presumed to induce damage).
- The output of the analysis should be the fatigue life in terms of repetitions of the load sequence, and stress cycles. Also plot the stress amplitudes (with SWT correction) in the SN-diagram.
- The stress is evaluated from strains measured at the surface of the bar a slight distance away from mid-span where the notch is located. Would the estimation of the fatigue life you have carried out with these stress magnitudes be conservative (on the safe side) or not?

APPENDIX – Rainflow count

See Dowling, sec 9.9.2 (and 9.9.3 if you like to add the calculation of an equivalent stress level – this is harder in the case of a fatigue limit; do you see why?).

You will need to create a function with a vector of the stress history as input and vectors (or a matrix) containing mid values and ranges (or amplitudes) of the stress cycles as output. The input data you get will start an end with the same value. Further, the data is “clean” in that it only contains (local) extreme values.

1. Re-organize your data to start with the largest magnitude
   a) Use the `max`-command to find the largest component and its position
   b) Assure that the last value is a duplicate of the first value. Remove it from the time series *and understand why it is removed.*
   c) Move all elements from the max value to the end of the vector to the beginning of the history
   d) Add the maximum element also to the end of the cycle *and understand why this is done.*
2. Identify stress cycles. Loop through all strain data elements until only three remains

a) Check if the difference to the next value (${}^{i+1}h \leftrightarrow^{i} h$) is larger than the difference to the previous value (${}^{i-1}h \leftrightarrow^{i} h$). If so, we have a cycle:

   i. Find the mid value and store in a vector

   ii. Find the amplitude and store in a vector

   iii. Store and remove the time increments ${}^{i-1}h$ and ${}^{i}h$ that are included in the cycles

   iv. Step back *at least* to the time increment before those affected (easiest is to start from the beginning)

b) Continue with the remaining values

3. If everything works as expected, you should eventually have three values left. These values form the final cycle.