ME 328 – Machine Design
Spring 2020, Homework Set 8

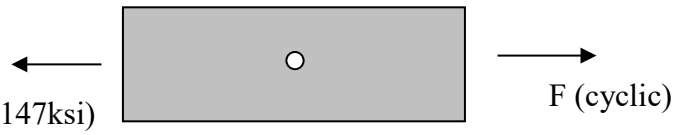
Unless otherwise stated, assume factor of safety of 1.0 and reliability of 99% for all problems.

***Education Purpose**: fatigue is one of the most important – and in my experience, **THE MOST IMPORTANT TOPIC in most of mechanical design.** Unfortunately, it is not possible to predict fatigue life with precision. None the less, the following questions are meant to provide some understanding of what factors affect fatigue life and how.*

1. (5 pts) What is the modified endurance limit (S_e) for machined 60 mm diameter hot rolled steel shaft (rotating bending load), operating at 500°C, assuming 95% reliability? Room temperature S_{UT} = 1600MPa.

2. (5 pts) A bar is subjected to a cyclic load. Use the following properties: yield strength = 54.3ksi, tensile strength = 85.5ksi, 10^3 cycle-strength = 64.1ksi, modified endurance limit = 25.1ksi. Determine the stress amplitude for 10^4 and 10^5 cycle-life assuming zero mean stress.

3. (10 pts) ***Educational Purpose**: realize that stress concentrations always have an effect on fatigue life, but the effect may be less in some materials.* The plate shown below is 0.250 inch thick, 4 inch wide, 20 inch long, with a 0.100 inch diameter hole in the middle. There is zero mean stress (F_{max} = - F_{min}). What is the fatigue stress concentration factor, K_f, due to the hole if the plate is:
   a) ASTM Grade 30 Gray Cast Iron
   b) 2024-T6 aluminum alloy
   c) AISI 1020 cold drawn steel
   d) AISI 1095 normalized steel (S_{UT}=147ksi)

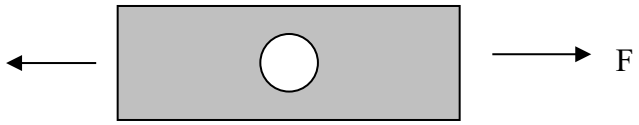


4. (10 pts) for AISI 1095 normalized steel axially loaded plate shown in problem 3, determine:
   a) Modified endurance limit
   b) Maximum allowable force amplitude (F) for infinite fatigue life assuming a factor of safety of 2 against fatigue.
   c) Maximum allowable force amplitude (F) such that there is no bulk yielding assuming factor of safety of 2 against yielding.

***Educational Purpose** of the next three problems: develop ability to analyze "non-zero mean stress" fatigue with and without stress concentrations. Fatigue failures almost always originate at stress concentrations, and since fatigue failure is a common occurrence, **this is a critically important subject**.*

5. (10 pts) Determine the stress amplitude (σ_a) required to cause fatigue failure at 50,000 cycles based on the following mean stresses. Assume factor of safety of 1, no stress concentration, yield strength of 54.3ksi, tensile strength of 85.5ksi, 10^3 cycle-strength of 64.1ksi (in other words, fS_{UT} = 64.1ksi), and modified endurance limit of 25.1ksi.
   a) σ_m = -10ksi; b) σ_m = 0ksi; c) σ_m = 10ksi

6. (15 pts) The plate shown below is made from plain carbon steel. It is 4 inches wide, 20 inches long, and has a 2.00 inch diameter hole in the middle. How thick must the plate be in order to survive 10^6 stress cycles (infinite life) with a fatigue factor of safety (FOS) of 2? Use a values of S_{ys}=75ksi, S_{UT}=S_{uts}=110ksi, S_e=48ksi (modified endurance limit). Consider force fluctuation of: F_{max} of 20,000 pounds tension and F_{min} of 8000 pounds compression.



7. (15 pts) Repeat problem 6, except now determine the thickness based on 10^3 stress cycles. Since fatigue life requirements are only 10^3 cycles, acceptable stress amplitude will be greater and therefore, plastic deformation (bulk yielding) may be more likely. Consider the following two different force fluctuations. Use FOS = 2 against fatigue failure.
   a) F_{max} of 20,000 pounds tension and F_{min} of 8000 pounds compression
   b) F_{max} of 8000 pounds tension and F_{min} of 20,000 pounds compression

8. (5 pts) Read the article by James G. Skakoon, *Exact Constraints* (Mechanical Engineering, Vol. 131, No. 9, September 2009, pp.32-36). A PDF copy is available on the course web page. Write a short description (less than half of a page) with sketches showing some design that either is or should be based on the concepts discussed. Do not use any of the examples from the article – select some other object for your discussion.

9. (5pts) **Educational purpose**: *so many more terms, so much less time….* Define the following terms, use sketches if appropriate, and cite your sources (URL's are acceptable): spherical rod end, sheave, babbitt bushing, burr, flashing, swarf.