ME 332 Design Project 1

Fall 2016

Due: Oct 25, 2016 by 12:00 pm to Rogers 334 (no late homework)

Please slide the homework under the door, or place on the shelving at the entrance to the room

In this project you will need to analyze heat transfer within a cylinder of an internal combustion engine and analyze thermal stress. Figure 1 provides a schematic of the cylinder. Note that the actual object is three dimensional and is axisymmetric. Your objective is to find cross sectional thickness L_3 which lowers the stress due to thermal expansion in both the shaft (blue) and outer ring of the piston (blue) to below yield. There is a constant heat generation (W/cm^3) inside the cylinder; this heat escapes through the head (shown as the brown walls) and through the piston. The piston is a rigid assembly comprising of a shaft (blue), top and bottom plates (grey), and ring (yellow). The bottom of the piston and the section of shaft outside of the piston are exposed to oil with a given convective coefficient and temperature. You may neglect radiative losses into the oil.

You will need to determine:

a) Heat transfer from cylinder (i.e. region with heat generation) to atmosphere through top and walls of head (brown).
b) Heat transfer from cylinder to piston.
c) All labeled temperatures.
d) Initial stress in brass ring due to thermal expansion (using provided L3).
e) Plot of temperature in fin as a function of distance from base to tip.
f) Once (a) through (e) are completed, calculate thickness L_3 of piston ring such that thermal stresses in shaft and ring are less than yield (target Safety Factor of 1.1 in ring while minimizing total mass).

Assumptions:

1. The black walls surrounding the piston have k=0.
2. The thermal expansion in the piston only acts in the vertical direction.
3. There is no convective or radiative heat transfer inside the piston (i.e. enclosed within the yellow).
4. All parts of the piston (top and bottom plates, ring, and shaft) are all rigidly bonded, meaning no separation can occur.
5. Top and bottom plates are infinitely stiff (i.e. no bending).
6. Use the convective heat transfer condition for the fin tip.
7. The surrounding temperature (i.e. Tsurr) is at T_∞.
8. Don't forget radiation emitted from the brown portion of the cylinder.

Deliverables:

1. Report
2. A copy of the completed table, which is provided. Do not change the format of the table. You will miss points if you do not keep the format.

3. Send the TA (Tyler Hudson, hudsont@oregonstate.edu) an electronic copy of your spreadsheet or code which was used for your analysis.
4. An appendix showing the details of your work (e.g. energy balance, equations used, etc.). This can be handwritten, but should be legible and show clearly what you did. The easier it is to understand the easier it is to provide credit.

Report:

Your report will be graded for being professional and complete. It is to be no longer than 2 pages. You want to convey the approach that you used, assumptions and constraints. Your report must include these sections for full credit: objective, approach (e.g., what equations or correlations did you use), design constraints, assumptions, solutions to items (a) – (f), and conclusions. Plots are encouraged.

Spreadsheet:

You need to determine the values for the spreadsheet provided. Email the completed spreadsheet and any code developed to Tyler Hudson (hudsont@oregonstate.edu) by the deadline. Please include “ME 332 Design Project 1” in the subject line. Save worksheet as “LastName_FirstName ME332 Design Project 1 Worksheet”.

Grading Matrix:

Correct answer (25%), correct approach (45%), and professional report (30%). **Because most of your points are earned by having the correct approach, be sure to articulate clearly and concisely the approach you took to determining a solution.**

Expectations:

You are encouraged to work with one partner in completing this assignment. However, you and partner are to do your work individually (i.e. you cannot copy from other groups). You will submit one set of deliverables.

Hints:

1. Start early.
2. Use engineering judgement. You will need to make assumptions. These should be listed.
3. Anticipate referencing multiple chapters from the book.
4. You can see the process I used in the spreadsheet (which you must complete). This may give you hints about an approach.
5. This is an optimization problem, so plan to iterate.
6. You may need to use solver functions to determine values.
7. It can be solved using Excel – avoid the trap of not being able to solve the problem because of coding challenges.
8. Do not forget about the contact resistance between piston plates (grey) and the shaft (blue) and ring (yellow).
9. You will need to iterate in order to find correct values for T11 and T12.

Useful Equations:

1. $\delta = CTE * \Delta T * l$ (free thermal deflection of a column), ΔT is reference to room temperature
2. $k = \frac{AE}{l}$ (stiffness of a column, A is cross sectional area, E is modulus of elasticity)

3. $\sigma_{ring} = \frac{\left(\frac{k_{shaft}}{k_{shaft}+k_{ring}}\right)*\Delta\delta*E}{l_{free}}$
4. $\sigma_{shaft} = \frac{\left(\frac{k_{ring}}{k_{shaft}+k_{ring}}\right)*\Delta\delta*E}{l_{free}}$
5. $l_{free} = \delta + l$ (this will be different for the shaft and the ring)
6. $\Delta\delta = \delta_{ring} - \delta_{shaft}$

Schematic:

Cross section shown is axisymmetric about the centerline.