ME 328 – Machine Design
Spring 2020, Homework Set 9

**Overall educational purpose**: *fasteners hold the mechanical world together…need I say more?*

Unless otherwise stated, assume factor of safety of 1. Most fasteners in the real world (but not all!) are steel. For this assignment, assume steel fasteners and therefore Young's modulus is 30Mpsi or 207GPa.

1) (5 pts) ***Educational purpose****: learn to determine and specify fastener torques.* Determine the torque required to tighten the following to 75% of proof load. Express answers in their respective units (part a –*US customary*, part b – SI (*not US*)).
    a) ¼-20 UNC SAE grade 5, cadmium plated
    b) M10 X 1.5 metric class 5.8, cadmium plated

   If by the time you need to solve this problem, in case we have not covered such things as "proof strength" or "proof load"…here's some hints. Proof load (force) is equal to Proof Strength (force per area) times the "effective" area of the fastener: $F_{proof} = S_p * A_t$. The "effective" area is referred to as the "tensile stress area" ($A_t$, found in Tables 8.1 and 8.2). The proof strength is defined by SAE, ASTM, or ISO standards … Tables 8.9-8.11. Equation 8.27 ($T=K F_i d$) and Table 8.15 will be handy. If a fastener is to be tightened to 90% of proof load, then $F_i = 0.9 F_{proof}$.

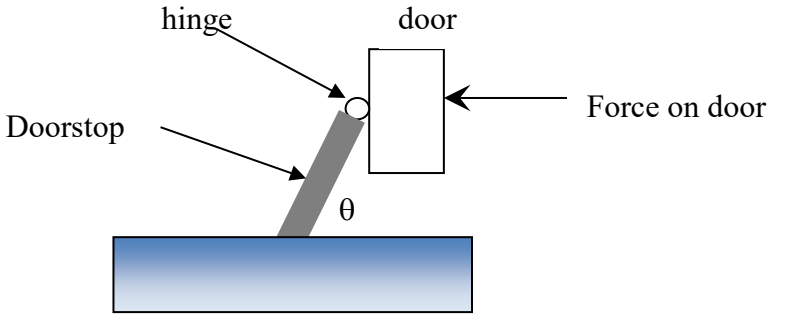
2) (5 pts) ***Educational purpose****: textbooks are awesome storage of human knowledge. However, since engineers must work in the physical world, they need to continually develop their physical senses. This exercise provides hands-on opportunity to interact with the physical world.* Near the plow-pulling test facility is a small box with several items in it: various fasteners (bolts, nuts, washers), wrenches, two thread gages (one ISO, one UN), and a blue fastener gage to determine diameter and other features of the bolts and the nuts. Fill in the tables at the end of this document for six fasteners.

3) (5 pts) ***Educational purpose****: apply static failure theory to thread-stripping and determine how a bolt/nut will fail.* The height of standard nuts is slightly less than its nominal diameter. In other words, the height of a ½-inch nut is slightly less than 1/2 of an inch (it is 7/16" = 0.4375"). Based on the maximum shear stress theory, show that if the length of thread engagement is at least one-half the diameter of the bolt, then a tension loaded capscrew (bolt) will yield across the diameter rather than stripping the threads. Assume the cross section of the bolt is "d" (the nominal diameter). As always, draw sketch and/or FBD. Hint: Assume the tension load is carried by shear through the threaded region and that the area is equal to the length of the thread which is equal to the "length" of the threads = (π*d)*(length of engagement). Strictly speaking, the diameter should be based on the minor diameter of the threads; however, to simplify the analysis for this problem, you may assume it is the nominal diameter (d).

**Educational purpose:** *The following questions/problems are meant broaden your understanding of design. We spend a great deal of time learning how to analyze engineering problems, but analysis is only a design tool.* ***You first and foremost need to understand how the***

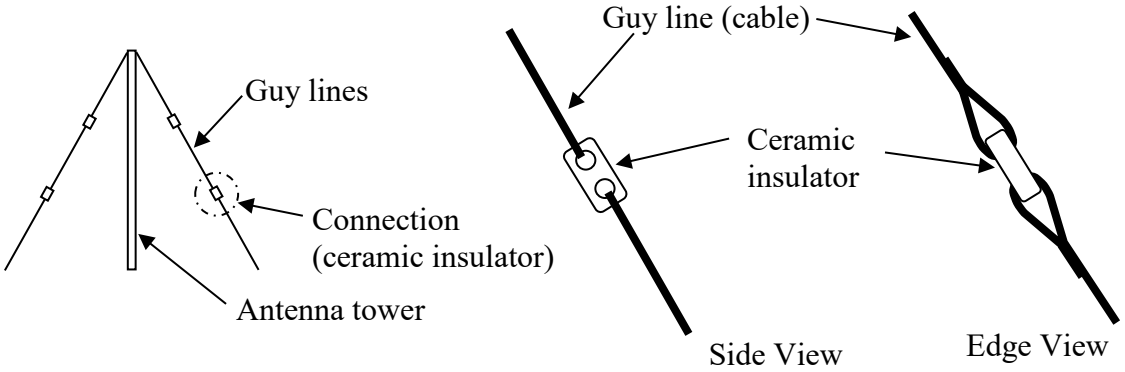
***world works, then apply that knowledge creatively to conceive viable solutions. Only then can you analyze or test to evaluate how viable the proposal is.***

4) (5 pts) Read the article by James G. Skakoon, *Self-Help* (Mechanical Engineering, Vol. 131, No. 7, July 2009, pp. 44-49). A PDF copy is available on the course web page. Briefly, explain how the concept of "self-help" could be applied to the door stop design shown below. Could this door stop be designed to prevent the door from moving regardless of how much force is applied (i.e. self-locking)? Assume the coefficient of friction between the doorstop and the floor is 0.6 is there an angle (θ) that would result in "self-locking"?




5) (5 pts) Draw two free-body diagrams for the slip-jaw wrench shown here; one for each of the two handles. For the orientation shown here, will this wrench design be self-helping if turned clockwise or counter clockwise or neither or both? A slip-jaw wrench will be available in the "fastener box" near the plow test facility for you to experience "hands on" learning. Please do not remove the plyers from the area.

6) (5 pts) Antenna tower guy-lines cannot be continuous otherwise they would interfere with the reception (electrical current would be generated in the wires which would then produce an interfering signal). So they are shortened and connected using ceramic insulators. The cables are looped through holes in the insulator and properly clamped. Comment on the following design for the ceramic insulator and offer a better alternative (better structurally and no worse economically).



7) (5 pts) **Educational purpose**: *mechanical engineering has its own jargon. So many terms, so little time….* Define the following terms, use sketches if appropriate, and cite your sources (URL's are acceptable): Belleville washer, wave washer, countersink, shoulder bolt, machine screw, fillet, chamfer, bevel, what's the difference between a machine screw and a bolt (hint: it has more to do with the installation than anything else).

***See next page for problem 2 tables.***

TABLES for Problem 2: Select 3 different UN and 3 different SI bolts.

Unified National (aka “standard” aka “English”) – UNF or UNC

| Nominal diameter** | Fine or coarse | Threads per inch | Nominal wrench size for standard hex head | Major diameter of threads* | Diameter of non-threaded shank* | Diameter of hole** | Clearance** | Fastener length | Thread length |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

SI (aka “metric”)

| Nominal diameter** | Fine or coarse | Thread pitch | Nominal wrench size for standard hex head | Major diameter of threads* | Diameter of non-threaded shank* | Diameter of hole** | Clearance** | Fastener length | Thread length |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

*Use the electronic caliper to measure these parameters

**Using the blue fastener gage, determine the nominal diameter of the bolts (if the bolt nicely fits in the hole marked with a ‘12’, then it is nominally a 12mm fastener… 12 mm ‘in name’). Then use the electronic caliper to measure the actual diameter of the hole in the blue fastener gage. Subtract the hole diameter from the shank diameter to determine clearance.

PLEASE LEAVE ITEMS IN THE AREA