

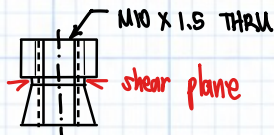


1) * Constraints

- ① No torque wrench (a nut and a bolt)
- ② Specific preload torque

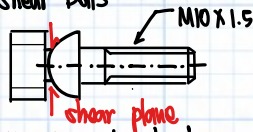
* Options

① Breakaway Nuts



The hex head attached to the smooth base breaks off when the target torque is applied.

② Shear Bolts



The hex head shears off when the torque applied to the head is beyond the requirement

There are other options such as tension indicating fasteners, TC bolts, and so on.

Shear bolt is chosen for the design due to:

- ① No external tool required
- ② Lower cost of manufacturing expected than tension indicating fasteners and TC bolts.

Commonly, nuts would be much cheaper to manufacture than bolts, but let's choose bolts instead bolts can also be used for threaded holes and have more versatility.



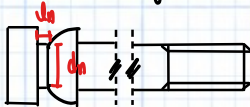
2) Assumptions:

- The mechanical properties of the bolt design are from the McMaster product given in the prompt
- The threading dimension will be based on the reference
- Mechanical properties

Tensile strength	110000 psi
shear strength	55000 psi
Thread fit	6g

* Solution 1

General drawing of the part



We need to solve for d_1 and d_2 to achieve the required torque limit
Let's assume that the neck fails due to only torsion, then

$$\tau_{max} = \frac{T \cdot d_1}{J} \quad (1)$$

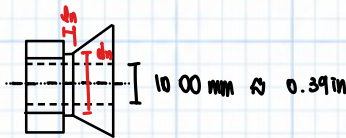
$$J = \frac{\pi d_1^4}{32} \quad (2)$$

$$\tau_{max} = \frac{16 T_{lim}}{\pi d_1^3} \quad (3)$$

$$d_1 = \left(\frac{16 T_{lim}}{\pi \tau_{max}} \right)^{\frac{1}{3}} = \left(\frac{16 \cdot 25 \text{ ft} \cdot \text{lbs}}{\pi \cdot 55000 \text{ psi}} \right)^{\frac{1}{3}} = \left(\frac{16 \cdot 25 \text{ ft} \cdot \text{lbs}}{\pi \cdot 55000 \text{ lbs/in}^2 \cdot 144 \text{ in}^2/\text{ft}^2} \right)^{\frac{1}{3}}$$
$$= 0.025 \text{ ft} \approx 7.62 \text{ mm}$$



* solution 2



assumption: The shear strength of the nut is the same as the bolt's.

$$\tau_{max} = \frac{T \frac{d_n}{2}}{J} \quad (1)$$

$$J = \frac{\pi}{32} (d_n^4 - d_b^4) = \frac{\pi}{32} (d_n^4 - (0.39 \text{ in})^4) \quad (2)$$

$$\tau_{max} = \frac{32 T \frac{d_n}{2}}{\pi (d_n^4 - (0.39 \text{ in})^4)} = \frac{16 T d_n}{\pi (d_n^4 - (0.39 \text{ in})^4)}$$

$$d_n^4 - (0.39 \text{ in})^4 = \frac{16 T}{\pi \tau_{max}} d_n \quad (3)$$

$$d_n^4 - \frac{16 T}{\pi \tau_{max}} d_n - (0.39 \text{ in})^4 = 0 \quad (4)$$

Plugging in the constraint variables, we get:

$$d_n^4 - \frac{16 \cdot 25 \text{ ft} \cdot \text{lb} \cdot 12 \text{ in/ft}}{\pi \cdot 55000 \text{ lbs/in}^2} d_n - (0.39 \text{ in})^4 = 0 \quad (5)$$

$$d_n^4 - 0.028 \text{ in}^3 d_n - 0.023 \text{ in}^4 = 0 \quad (6)$$

$$d_n \approx 0.442, -0.383 \quad (7)$$

since the dimension is strictly positive, $d_n \approx 0.442 \text{ in} \approx 11.3 \text{ mm}$

In the same manner as the solution 1,

$$\phi = \frac{T d_n}{G J} \Rightarrow d_n = \frac{\phi G J}{T} \quad (8)$$

$$\begin{aligned} d_n &= \frac{\pi G (d_n^4 - (0.39 \text{ in})^4)}{32 T} \phi \\ &= \frac{\pi (1.6 \times 10^7 \text{ psi}) (0.442 \text{ in})^4 - (0.39 \text{ in})^4}{32 \cdot 25 \text{ lb} \cdot \text{ft} \cdot 12 \text{ in/ft}} \phi \\ &= 79.69 \phi \text{ in} \end{aligned}$$



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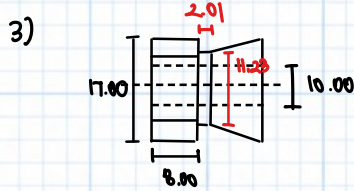
Class: TAM 251

Assignment: Discussion #7

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Checked by: _____ Signed: _____ Date: _____

Let's assume $\phi = 0.001$, then $\Delta h = 0.0791 \text{ m} \approx 2.01 \text{ mm}$



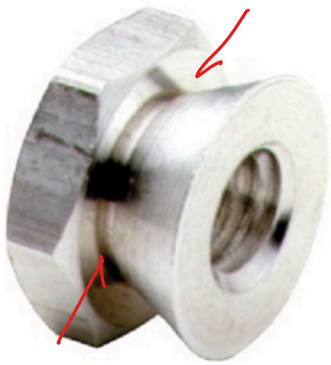
Note: The schematic is not drawn in scale
⊙ unit: mm

In fact, there are already products for solving this problem:

① Shear bolts (discussed above)



② Breakaway nuts



③ TC bolts (requires a special tool to tighten)



and so on...