Solid Mechanics I

Course homepage

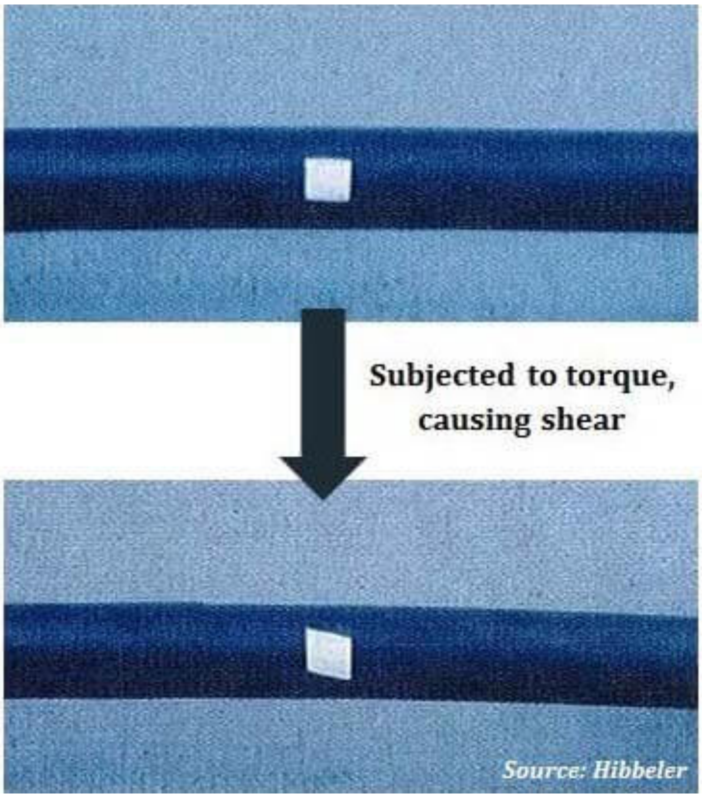
(http://www.engineeringcorecourses.com/solidmechanics1)

C3: Torsion (http://www.engineeringcorecourses.com/solidmechanics1/C3-torsion/overview)

C3.1 Torsion Formula

Torsion is basically the stress due to torque. Many structures experience torque (e.g. torque wrench, car shaft, etc) and therefore it is important to quantify the stress caused by torque to help us design safe structures.

Torsion applies *shear* rather than normal stress, as seen in the illustration below:

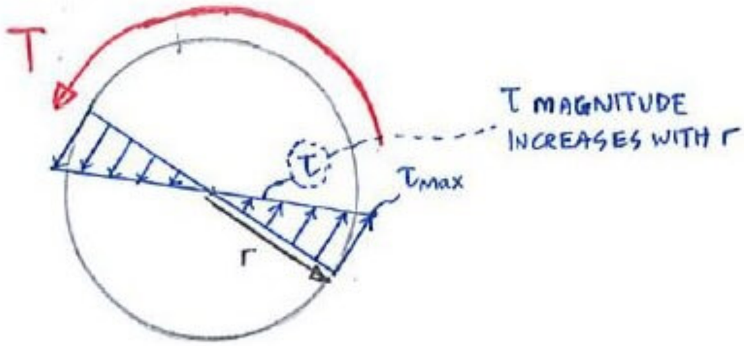


Torsion formula

The torsional shear stress can be calculated using the following formula:

Torsion formula

Formula: $$\boxed{\tau = \frac{Tr}{J}}$$ (Units: $\boldsymbol{Pa}$ or $\boldsymbol{MPa}$)



Note:

- T is the *internal torque* at the region of interest, as a result of external torque loadings applied to the member (units: Nm)
- r is the radius of the point where we are calculating the shear stress (units: m or mm)
- J is the *polar moment of inertia* for the cross-section (units: m^4 or mm^4)

Notice that the higher the radius r, the higher the torsional shear stress. Therefore at $\mathrm{r}_{\mathrm{max}}$, we have τ_{max}. We usually denote $\mathrm{r}_{\mathrm{max}}$ as c:

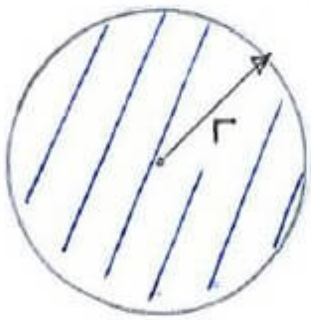
Formula: $$\tau_{max} = \frac{Tc}{J}$$

Polar moment of inertia, J

This variable basically measures the resistance to torsional loading. It is a function of the geometry (not mass); the larger the cross-section, the bigger the polar moment of inertia.

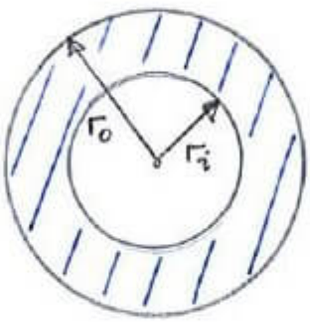
We mostly deal with *solid* or *hollow* circular cross-sections:

Solid



$$J = \frac{\pi}{2} r^4 = \frac{\pi}{32} D^4$$

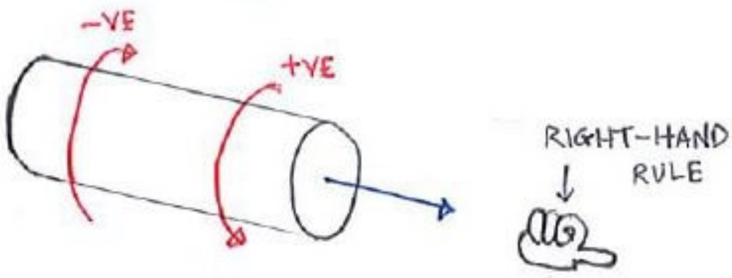
Hollow



$$J = \frac{\pi}{2}\left(r_o^4 - r_i^4\right) = \frac{\pi}{32}\left(D_o^4 - D_i^4\right)$$

Sign convention

We use the *right-hand rule* as our positive sign convention. First we define an axis direction, then all torque directions are determined according to the axis and the right-hand rule:



Let's look at an example (http://www.engineeringcorecourses.com/solidmechanics1/C3-torsion/C3.1-torsion-formula/example) now.

(http://www.engineeringcorecourses.com/)