Mechanics of Materials II:

Thin-Walled Pressure Vessels and Torsion

Dr. Wayne Whiteman
Senior Academic Professional and Director of the Office of Student Services
Woodruff School of Mechanical Engineering

Georgia Institute of Technology

Module 2 Learning Outcomes

- Define the qualifications for a structure to be treated as a thin-walled pressure vessel
- Give examples of thin-walled pressure vessels
- Determine a method for analyzing thin-walled pressure vessels

Mechanics of Materials

Foundation for all structural and machine design

ENGINEERING STRUCTURE → EXTERNAL LOADS → INTERNAL FORCES AND MOMENTS → STRESSES / STRAINS → STRUCTURAL PERFORMANCE

- Axial
- Torsional (Twisting)
- Transverse/Flexural/Bending
- Pressure
- Combined Loading

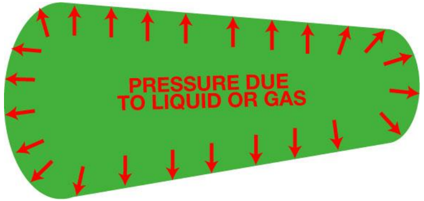
- deformations/deflections
- yield/fracture
- success/failure?

Mechanics of Materials

Georgia Tech

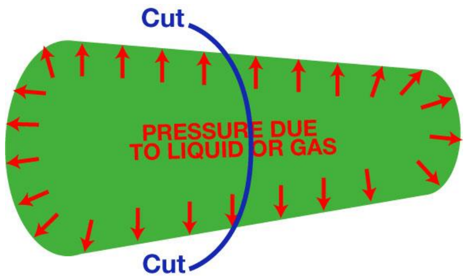
Foundation for all structural and machine design

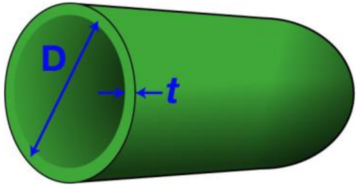
ENGINEERING STRUCTURE → EXTERNAL LOADS → INTERNAL FORCES AND MOMENTS → STRESSES / STRAINS → STRUCTURAL PERFORMANCE



Thin-Walled Pressure Vessels

Let’s look at a section cut

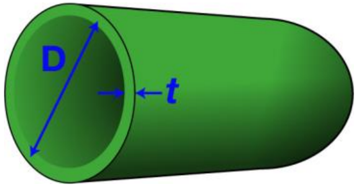




Thin-walled ≡ ratio of wall thickness to diameter of the vessel is so small that the distribution of normal stress on a cut is essentially uniform through the thickness of the shell

(stress is actually max on the inside and min on the outside [free surface])

Thin-Walled Pressure Vessels



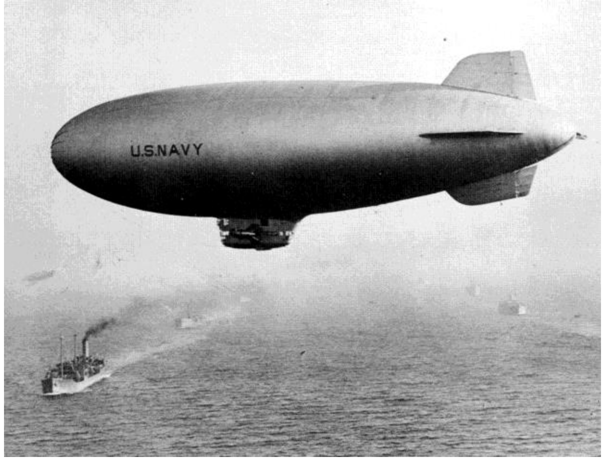
Thin-walled ≡ ratio of wall thickness to diameter of the vessel is so small that the distribution of normal stress on a cut is essentially uniform through the thickness of the shell

$$D_{inner} \approx D_{outer} \approx D$$

$$\frac{D}{t} \geq 20$$ to qualify as a thin-walled pressure vessel

Thin-Walled Pressure Vessels

Examples: **Boilers, gas storage tanks, pipelines, blimps, etc.**



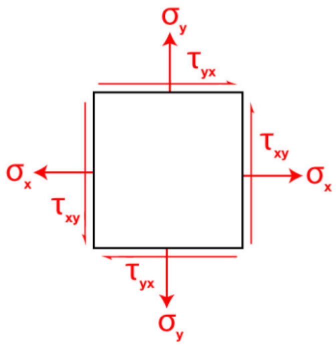
Should we use Plane Stress or Plane Strain in analyzing thin-walled pressure vessels?

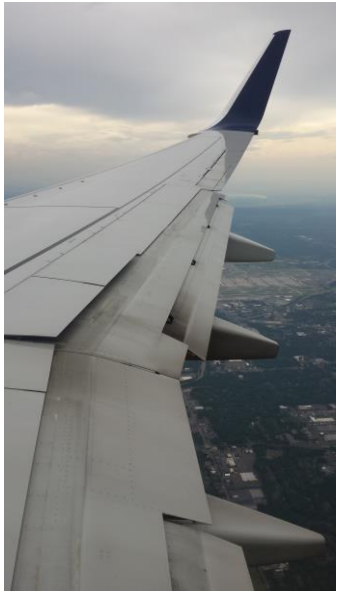
You must use engineering judgment in modeling and be aware of the assumptions you are making!

Two-Dimensional (2D) or Plane Stress

$$\sigma_z = \tau_{xz} = \tau_{zx} = \tau_{yz} = \tau_{zy} = 0$$

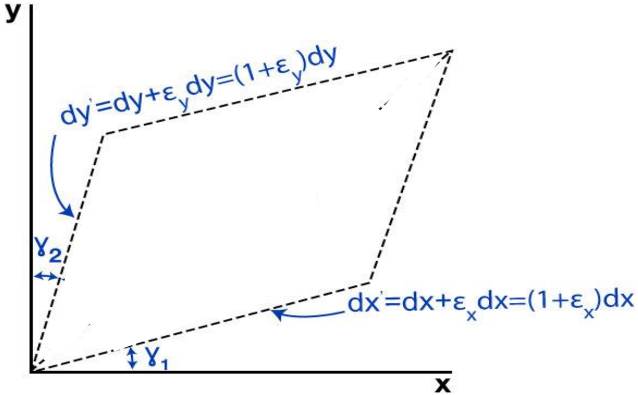
All real world stress situations are three-dimensional, but the plane stress assumption can simplify the analysis without significantly affecting the results. A common example when plane stress might be used is the analysis of thin plates such as the skin panels on aircraft wings.





Plane Strain

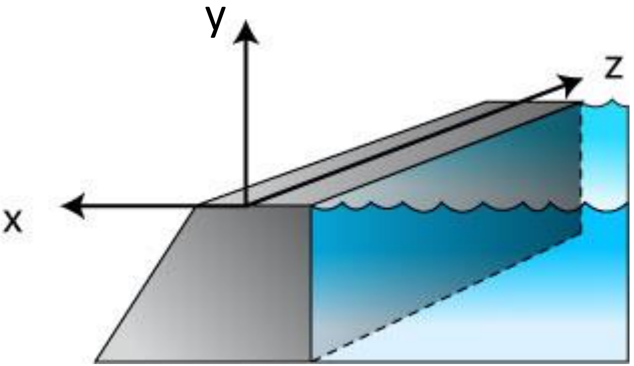
$$\varepsilon_z = \gamma_{xz} = \gamma_{zx} = \gamma_{yz} = \gamma_{zy} = 0$$



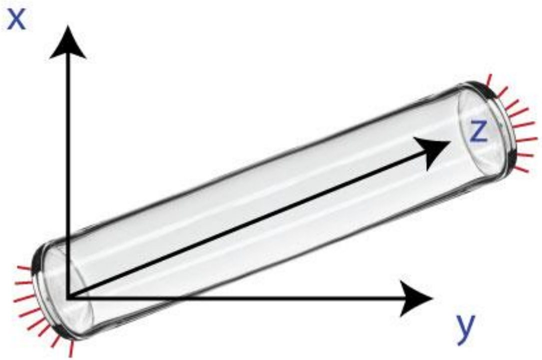
No strains in z-direction.
But there can be stresses in the z-direction

Large relative dimension in z-direction with restraints to prevent strain in z-direction

Dams, Retaining Walls, Tunnels

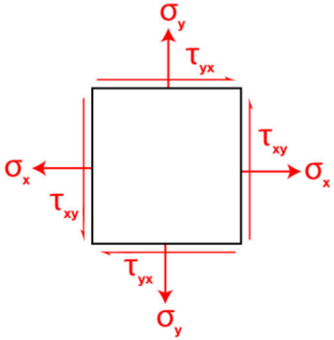


Bars, tubes, etc. compressed by forces normal to their cross-section



Two-Dimensional (2D) or Plane Stress

$$\sigma_z = \tau_{xz} = \tau_{zx} = \tau_{yz} = \tau_{zy} = 0$$



Stresses on outer surface are plane stress (stress-free surface)