

23CE302 : STRENGTH OF MATERIALS

Mr. A SRINIVAS

Assistant Professor, Civil Engineering
Narsimha Reddy Engineering College (Autonomous)
Secunderabad, Telangana, India- 500100.



NARSIMHA REDDY ENGINEERING COLLEGE
UGC AUTONOMOUS INSTITUTION

Maisammaguda (V), Kompally - 500100, Secunderabad, Telangana State, India

UGC - Autonomous Institute
Accredited by **NBA** & **NAAC** with '**A**' Grade
Approved by **AICTE**
Permanently affiliated to **JNTUH**

UNIT-V Thin Cylinders and Thick Cylinders

- **Topics Covered**

- Thin Cylinders
- Thin Spherical Shells
- Thick Cylinders
- Lamé's Theory
- Compound Cylinders
- Shrink Fit

Learning Outcomes

- After studying this unit, students will be able to:
- Define thin and thick pressure vessels.
- Derive hoop and longitudinal stress equations.
- Calculate strains and dimensional changes.
- Explain thin spherical shells.
- Apply Lamé's theory for thick cylinders.
- Design thick cylinders.
- Understand compound cylinders and shrink fitting.

Pressure Vessels

- **Definition**
- A **pressure vessel** is a closed container designed to hold gases or liquids at pressures different from atmospheric pressure.
- **Applications**
 - Boilers
 - LPG cylinders
 - Gas storage tanks
 - Hydraulic cylinders
 - Pipelines
 - Air compressors
- **Classification**
 - Thin Cylinders
 - Thick Cylinders
 - Spherical Shells

Thin Cylinders

- **Definition**

- A cylinder is considered **thin** when

- $\frac{D}{t} > 20$

- Where

- D = Diameter

- t = Thickness

- **Assumptions**

- Wall thickness is uniform.

- Stress is uniformly distributed.

- Radial stress is negligible.

- Material is homogeneous and isotropic.

Hoop (Circumferential) Stress

- **Hoop Stress**
- Acts around the circumference.
- **Derivation**
- Equating internal pressure force and resisting force,
- $\sigma_h = \frac{PD}{2t}$
- Where
- P = Internal pressure
- D = Diameter
- t = Thickness
- **Important Point**
- Hoop stress is the maximum stress in a thin cylinder.

Hoop and Longitudinal Strains

- Using Hooke's Law,
- **Hoop Strain**
- $\varepsilon_h = \frac{\sigma_h}{E} - \mu \frac{\sigma_l}{E}$
- **Longitudinal Strain**
- $\varepsilon_l = \frac{\sigma_l}{E} - \mu \frac{\sigma_h}{E}$
- Where
- E = Young's Modulus
- μ = Poisson's Ratio

Change in Diameter

- **Formula**

- $\Delta D = \varepsilon_h D$

- Where

- ΔD = Increase in diameter

- **Observation**

- Higher internal pressure produces greater expansion.

Change in Length and Volume

- **Change in Length**

- $\Delta L = \varepsilon_l L$

- **Volumetric Strain**

- $\varepsilon_v = 2\varepsilon_h + \varepsilon_l$

- **Change in Volume**

- $\Delta V = \varepsilon_v V$

Thin Spherical Shells

- **Definition**

- A spherical pressure vessel with

- $\frac{D}{t} > 20$

- **Stress Formula**

- $\sigma = \frac{PD}{4t}$

- **Observation**

- Only one tensile stress acts.
- Stress is equal in every direction.
- Applications
 - LPG tanks
 - Gas storage spheres
 - Pressure vessels

Thick Cylinders

- **Definition**
- A cylinder is considered thick when
- $\frac{D}{t} < 20$
- **Examples**
- Gun barrels
- Hydraulic presses
- High-pressure pipes
- Pressure reactors
- **Characteristics**
- Stress varies across thickness.

Lame's Theory

- **Assumptions**

- Material is elastic.
- Cylinder is homogeneous.
- Radial displacement is small.
- Stress varies across thickness.

- **Two Stresses**

- Radial Stress
- Hoop Stress

Lame's Formula

- **Radial Stress**

- $\sigma_r = A - \frac{B}{r^2}$

- **Hoop Stress**

- $\sigma_h = A + \frac{B}{r^2}$

- Where

- A and B are constants

- r = Radius

Stress Distribution

- **Radial Stress**
 - Maximum at inner surface
 - Zero at outer surface
- **Hoop Stress**
 - Maximum at inner radius
 - Decreases toward outer radius
- **Design Consideration**
 - Failure generally starts at the inner surface.

Design of Thick Cylinders

- Design depends upon
 - Internal pressure
 - Outer pressure
 - Allowable stress
 - Material strength
 - Wall thickness
- **Design Procedure**
 - Determine allowable stress.
 - Apply Lame's equations.
 - Calculate required thickness.
 - Check safety.

Compound Cylinders

- **Definition**
- Two cylinders assembled together to withstand higher pressure.
- **Advantages**
- Higher strength
- Better stress distribution
- Increased pressure capacity
- Reduced maximum hoop stress
- Applications
- Heavy guns
- High-pressure hydraulic cylinders

Shrink Fit (Compound Cylinders)

- **Principle**
- Outer cylinder is heated.
- Inner cylinder is cooled.
- After assembly,
- Outer cylinder contracts.
- Compressive stresses develop.
- Internal pressure capacity increases.
- **Necessary Difference of Radii**
- Called **Shrinkage Allowance**
- Depends on
- Material
- Interference
- Elastic modulus

Summary

- **Key Takeaways**

- ✓ Thin cylinder: $D/t > 20$
- ✓ Thick cylinder: $D/t < 20$
- ✓ Hoop stress = $PD/2t$
- ✓ Longitudinal stress = $PD/4t$
- ✓ Hoop stress is twice longitudinal stress
- ✓ Thin sphere stress = $PD/4t$
- ✓ Lame's equations are used for thick cylinders
- ✓ Hoop stress is maximum at inner surface
- ✓ Compound cylinders improve strength
- ✓ Shrink fitting increases pressure-carrying capacity