# 23CE302 : STRENTH OF MATERIALS


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# UNIT-V Thin Cylinders and Thick Cylinders

- **Topics Covered**
- Thin Cylinders
- Thin Spherical Shells
- Thick Cylinders
- Lame'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 Lame'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