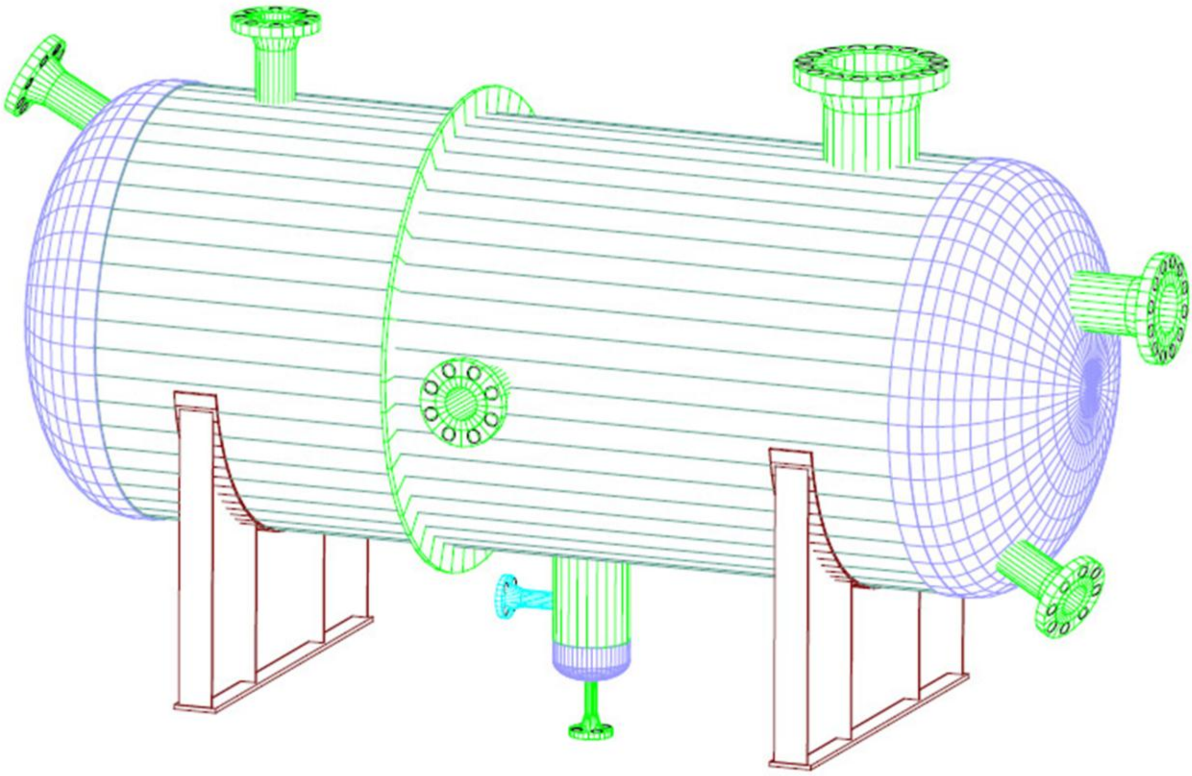
University of Technology
Mechanical Engineering Department

Machine Design I

Third Class for All Branches

LECTURES TWENTY TWO

PRESSURE CYLINDERS



Introduction:

Internally pressurized cylinders have a variety of uses in mechanical equipment. They may be classified variously as below:

1. According to Dimensions:

a) Thin $\left\{\frac{t}{d} \leq 0.1\right\}$

b) Thick $\left\{\frac{t}{d} > 0.1\right\}$

2. According to end construction:

a) Open end

b) Closed end

3. According to material:

a) Brittle material

b) Ductile material

4. According to service:

a) Pressure

b) Temperature

c) Environment

Thin walled cylinder

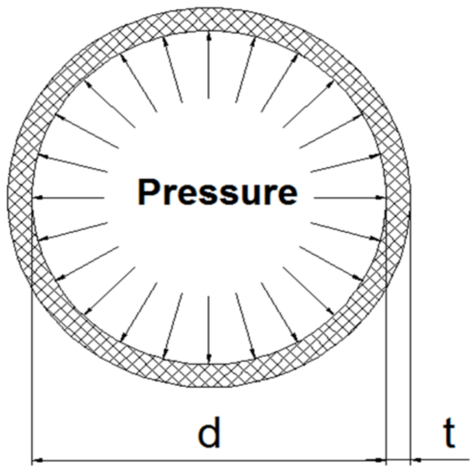
σ_h = Circumferntial stress

σ_L = Longitudinal stress

P = Internal Pressure

d = Internal diameter

t = Wall thickness

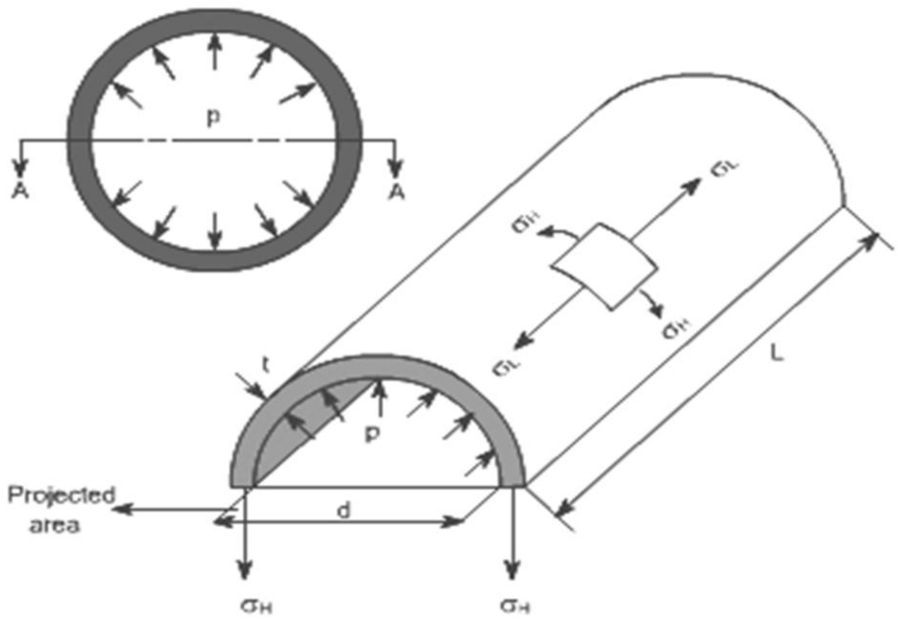


Circumferential tensile stress

$$P * d * L = \sigma_h * 2 * t * L \qquad \therefore \quad \left\{ \frac{t}{d} = \frac{P}{2\sigma_h} \right\} \text{........} (1)$$

Longitudinal tensile stress

$$P * \frac{\pi d^2}{4} = \sigma_L * \pi d_m * t \qquad \therefore \quad \left\{ \frac{t}{d} = \frac{P}{4\sigma_L} \right\} \text{........} (2)$$



Thick cylinders

When the wall thickness of cylinder is large relative to its diameter the following equations may be used:

Note: *The detail of deriving the equations when the consideration of a cross section of a cylinder perpendicular to its axis will not take in our analysis.*

1. Lame's equations:

a) For Brittle material

$$\boldsymbol{t = \frac{d}{2}\left(\sqrt{\frac{[\sigma] + P}{[\sigma] - P}} - 1\right)} \quad \ldots\ldots\ldots (\mathbf{3})$$

- Based on Normal stress theory.
- Used for open and closed ends.

b) For Ductile material

$$\boldsymbol{t = \frac{d}{2}\left(\sqrt{\frac{[\tau]}{[\tau]-P}}\ -1\right)} \ldots\ldots\ldots(\mathbf{4})$$

- Based on maximum shear stress theory.
- Used for open and closed ends.

2. Birnie's equation

$$\boldsymbol{t = \frac{d}{2}\left(\sqrt{\frac{[\sigma]+(1+\upsilon)\,P}{[\sigma]-(1+\upsilon)\,P}}\ -1\right)} \ldots\ldots\ldots(\mathbf{5})$$

- Based on maximum strain theory
- For open end cylinder
- Used for Ductile material

3. Clavarino's equation

$$\boldsymbol{t = \frac{d}{2}\left(\sqrt{\frac{[\sigma]+(1-2\upsilon)P}{[\sigma]-(1+\upsilon)P}}\ -1\right)} \ldots\ldots\ldots(\mathbf{6})$$

- Based on maximum strain theory
- For closed end cylinder
- Used for Ductile material

Where: $\boldsymbol{\upsilon}$ = Poisson's ratio

$\boldsymbol{\upsilon} = (0.28 - 0.3)$ for steel
$\boldsymbol{\upsilon} = 0.26$ for Cast Iron
$\boldsymbol{\upsilon} = 0.36$ for Bronze
$\boldsymbol{\upsilon} = 0.33$ for Alminum

Cylinder heads thickness

$$h = d\sqrt{\frac{C*P}{[\sigma]}} \quad = \text{Cover thickness}$$

Where:

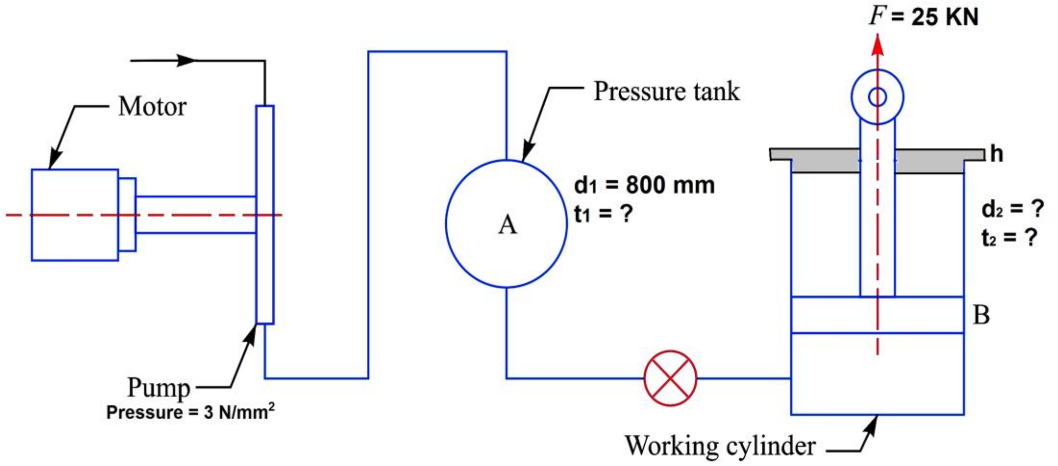
C = 0.162 for bolted cover and if it's integral with cylinder
= 0.2 for riveted joints
= (0.25-0.3) for welded joint

[σ] = Permissible stress

Example

A hydraulic control for a straight line motion, as shown in Fig. below, utilizes a spherical pressure tank 'A' connected to a working cylinder B. The pump maintains a pressure of 3 N/mm2 in the tank.

1. If the diameter of pressure tank is 800 mm, determine its thickness for 100% efficiency of the joint. Assume the allowable tensile stress as 50 MPa.
2. Determine the diameter of a cast iron cylinder and its thickness to produce an operating force F = 25 kN. Assume (i) an allowance of 10 per cent of operating force F for friction in the cylinder and packing, and (ii) a pressure drop of 0.2 N/mm2 between the tank and cylinder. Take safe stress for cast iron as 30 MPa.
3. Determine the power output of the cylinder, if the stroke of the piston is 450 mm and the time required for the working stroke is 5 seconds.
4. Find the power of the motor, if the working cycle repeats after every 30 seconds and the efficiency of the hydraulic control are 80 percent and that of pump 60 percent.



Solution:

- **To find t_1 :** check the sphere thin or thick $\left\{\frac{t_1}{d_1} = \frac{P}{4\sigma}\right\}$

Now use equation (2) because on sphere there is longitudinal tensile stress

$\frac{t_1}{d_1} = \frac{3}{4*50} = 0.015 \quad < \quad 0.1 \quad \therefore \ cylinder \ is \ thin$

$$\therefore \ t_1 = \frac{1.5*800}{100} = 12 \text{ mm}$$

- **To find t_2 & d_2 :** check the sphere thin or thick $\left\{\frac{t_2}{d_2} = \frac{P}{2\sigma}\right\}$

$$\frac{t_2}{d_2} = \frac{(3-0.2)}{2*30} = 0.0467 \quad < \quad 0.1 \quad \therefore cylinder \ is \ thin$$

F_{Total} = P * Area $\quad \therefore \quad (25000*1.1) = 2.8*\frac{\pi d_2^2}{4} \quad \rightarrow \quad d_2 = 112 \ mm$

- **To find the power:**

Power = $\frac{Work}{time} = \frac{(25000*1.1)*0.45}{55} = 2475 \ Watt$

- **To find the power of motor** = $\frac{2475}{0.6*0.8} = 5156.25 \ Watt$