CH0401 Process Engineering Economics

Lecture 4a

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Process Engineering Economics

1. **Economic Analysis**
2. Economic Balance in Cyclic Operation

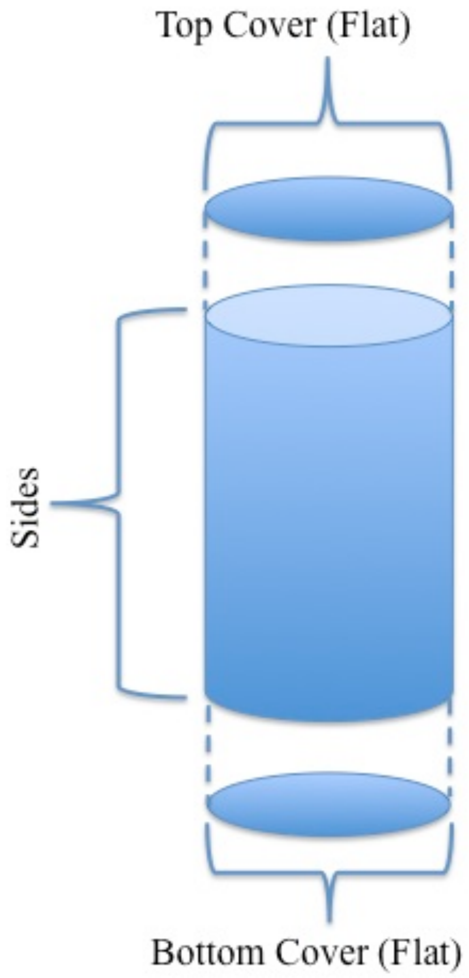
Process Engineering Economics

1 Economic Analysis

2 Economic Balance in Cyclic Operation

Process Engineering Economics – *Economic Analysis*

Optimum proportions for a cylindrical container



The surface area (A) of the cylinder (closed) is given as the sum of the area of Sides, top and bottom covers of the cylinder

i.e.

$$A = (\pi \times D \times L) + \left(\frac{\pi}{4} D^2\right) + \left(\frac{\pi}{4} D^2\right)$$

$$A = (\pi \times D \times L) + 2\left(\frac{\pi}{4} D^2\right)$$

Where D = Vessel Diameter

L = Vessel Length (or Height)

Process Engineering Economics – *Economic Analysis*

$$A = (\pi \times D \times L) + 2\left(\frac{\pi}{4}D^2\right)$$

The above equation is minimized, simplified and solved to identify the minimum surface area required for cylinder with a given volume

$$f(D \times L) = (D \times L) + \left(\frac{D^2}{2}\right) - - - (A)$$

For a given volume (*V*), the diameter and length are related by

$$V = \left(\frac{\pi}{4} \times D^2 \times L\right)$$

and

$$L = \left(\frac{4V}{\pi D^2}\right) - - - - - - - (B)$$

Process Engineering Economics – *Economic Analysis*

Now the equation (A) becomes

$$f(D) = \left(\frac{4V}{\pi D}\right) + \left(\frac{D^2}{2}\right)$$

Differentiating the above function and setting it to zero will give the optimum value for D

$$\left(-\frac{4V}{\pi D^2}\right) + D = 0$$

$$D = \sqrt[3]{\frac{4V}{\pi}}$$

From equation (B), the corresponding length will be

$$L = \sqrt[3]{\frac{4V}{\pi}}$$

Process Engineering Economics – *Economic Analysis*

Therefore, for a cylindrical container the minimum surface area to enclose a given volume is obtained when *length is made equal to the diameter*.

Process Engineering Economics – *Economic Analysis*

Example Problem: It is required to determine the optimum diameter to height ratio for a large oil storage vessel, so that the total cost is minimum. Following data may be used for the calculation

C_s = cost of sides per square meter

C_h = cost of the head or top per square meter = 1.5 C_s

C_b = cost of the bottom per square meter = 0.75 C_s

Process Engineering Economics – *Cyclic Process*

The surface area (A) of the cylinder (closed) is given as the sum of the area of Sides, top and bottom covers of the cylinder

i.e. $$A = (\pi \times D \times H) + \left(\frac{\pi}{4} D^2\right) + \left(\frac{\pi}{4} D^2\right)$$

Let C_T = total cost of the vessel
D = Vessel Diameter
H = Vessel Height

then

$$C_T = C_s(\pi \times D \times H) + C_b\left(\frac{\pi}{4} D^2\right) + C_h\left(\frac{\pi}{4} D^2\right) - - - - - - -(1)$$

$$C_T = C_s(\pi \times D \times H) + (C_b + C_h)\left(\frac{\pi}{4} D^2\right) - - - - - - -(2)$$

Process Engineering Economics – *Cyclic Process*

$$V = \left(\frac{\pi}{4} \times D^2 \times H \right)$$

(or)

$$H = \left(\frac{4V}{\pi D^2} \right)$$

Substituting for equation *H* in equation (2) shown in slide 09

$$C_T = C_s \left(4\frac{V}{D} \right) + (C_b + C_h)\left(\frac{\pi}{4} D^2 \right) ------(3)$$

Differentiating with respect to design variable *D* and equating to zero

$$\frac{dC_T}{dD} = \frac{-4C_s V}{D^2} + (C_b + C_h)\frac{\pi D}{2}$$

Process Engineering Economics – *Cyclic Process*

$$D^3 = \left[\frac{C_s}{C_b + C_h}\right] \times \frac{8V}{\pi} -------(4)$$

Substituting for the volume in (4) in terms of D and H gives the following optimum D to H ratio for the minimum cost of the vessel.

$$\frac{D}{H} = \frac{2C_s}{C_b + C_h} -------(5)$$

Substituting for C_b and C_h in terms of C_s gives the optimum D to H

$$\boxed{\frac{D}{H} = \frac{2C_s}{(0.75 + 1.5)C_s}}$$

Process Engineering Economics – ***References***

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