classmate
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20CH30020

FLUID FLOW AND DESIGN LAB

ASSIGNMENT - 5

Given →

→ Vessel Height = 25 m (H)
→ Maximum operating Pressure = 2 MPa (P_o)

considering 5% safety
⇒ Design Pressure = 1.05 × 2 MPa
= 2.1 MPa

we have from previous Assignment
→ t_a = 28mm
corroded shell Thickness = 28 mm − 2mm
= 26 mm

→ ID of vessel = 2 m
→ γ_s = 7.7×10^4 N/m²

Now, we know
→ $W_{min} = \pi (D_i + t_a) t_a H \gamma_s$

$= \pi (2 + 28\times10^{-3})(28\times10^{-3})(25)\times(7.7\times10^4)$

$= 343.405$ kN

→ W_e = weight of water

$= \frac{\pi D_i^2}{4} \times h_{shell} \times g \times \rho_w$

$= \frac{\pi}{4} \times 2^2 \times 25 \times 9.81 \times 1000$

$= 770.475$ kN

$\rightarrow$ $W_{max} = W_{min} + W_e$

$= (343.405 + 770.475)$ kN

$= 1113.879$ kN

$\rightarrow$ $T_{min} = 6.35 \times 10^{-5} \times \left(\frac{H}{D}\right)^{3/2} \times \left(\frac{W_{min}}{t}\right)^{1/2}$

$= 6.35 \times 10^{-5} \times \left(\frac{25+5}{2}\right)^{3/2} \times \left(\frac{343.405}{0.026}\right)^{1/2}$

$= 0.424$ s

Since T_{min} (0.424 s) < 0.5 s $\Rightarrow K_1 = 1$

$\rightarrow$ $T_{max} = 6.35 \times 10^{-5} \times \left(\frac{25+5}{2}\right)^{3/2} \times \left(\frac{1113.879}{0.026}\right)^{1/2}$

$= 0.763$ s

Since T_{max} (0.763 s) > 0.5 s $\Rightarrow K_2 = 2$

Now we know

$P_w = K_1 K_2 P_w H D$

$\rightarrow$ $P_w (min) = 0.7 \times 1 \times (0.05 \times 150^2) \times 2 \times 30$

$= 47.25$ kN

$\rightarrow$ $P_w (max) = 0.7 \times 2 \times (0.05 \times 150^2) \times 2.056 \times 30$

$= 97.15$ kN

→ $M_{w(min)} = P_{w(min)} \times \frac{h}{2}$ (h → total height)

$= 47.25 \times \frac{30}{2}$

$= 708.75$ kN m

→ $M_{w(max)} = P_{w(max)} \times \frac{h}{2}$

$= 97.15 \times \frac{30}{2}$

$= 1457.25$ kNm

→ Now we have

$$\sigma_{zwm}(min) = \frac{4 M_{w(min)}}{\pi D^2 t} = \frac{4 \times 708.75}{\pi \times 2^2 \times t}$$

$$= \frac{225.602}{t} \text{ kPa}$$

$$\sigma_{zwm}(max) = \frac{4 M_{w(max)}}{\pi D^2 t} = \frac{4 \times 1457.25}{\pi \times 2^2 \times t}$$

$$= \frac{463.857}{t} \text{ kPa}$$

$$\sigma_z(min) = \frac{W_{min}}{\pi D_o t} = \frac{343.405}{\pi \times 2 \times t}$$

$$= \frac{54.65}{t} \text{ kPa}$$

NOTE ⇒ Since shell thickness is very small as compared to the diameter, therefore we can write $D_o \approx D_i \Rightarrow D_o = 2\,m.$ (Approx.)

$$\sigma_z(max) = \frac{W_{max}}{\pi D_o t} = \frac{1113.879}{\pi \times 2 \times t} = \frac{177.279}{t}\ kPa$$

we have calculated in Assignment 4 that

$$M_s = 0.038\,x \times 10^6\ Nm$$

we have $x = 30\ m$ for full height.

$$\sigma_{zsm}(max) = \frac{4M_s}{\pi D^2 t} = \frac{4 \times 0.038 \times 30 \times 10^6}{\pi \times 4 \times t} = \frac{362.873}{t}\ kPa$$

Maximum Tensile strength

$$\sigma_z = \sigma_{zwm}(max) + \sigma_{zsm}(max) - \sigma_{zw}(min)$$

$$= \frac{463.857}{t} + \frac{362.873}{t} - \frac{54.65}{t} \quad \text{— (I)}$$

we also know

$$\sigma_z = f\,J$$

$$= 0.85 \times 100 \times 10^3 \times 10^3$$

$$= 85 \times 10^3\ kPa$$

$$= 85\ MPa \quad \text{— (II)}$$

From (I) and (II)

$$85 \times 10^3 = \frac{463.857}{t} + \frac{362.873}{t} - \frac{54.65}{t}$$

$$\frac{772.08}{t} = 85 \times 10^3$$

$$t \Rightarrow 9.083\ mm$$

Maximum Compressible stress

$$\sigma_z = \sigma_{zwm\,(max)} + \sigma_{zsm\,(max)} + \sigma_{zw\,(max)}$$

$$= \frac{463.857}{t} + \frac{362.873}{t} + \frac{177.279}{t} \quad - \text{(I)}$$

we also know

$$\sigma_z = \frac{0.125\, E t}{D_o}$$

$$= \frac{0.125 \times \cancel{2} \times 10^5 \times t \times 10^6}{\cancel{2}} \quad - \text{(II)}$$

From (I) and (II), we get

$$t^2 = \left(\frac{463.857 + 362.873 + 177.279}{0.125 \times 10^{11}}\right) \times 10^3$$

$$t = 8.961 \text{ mm}$$

Higher thickness = 9.083 mm

Actual skirt thickness = (9.083 mm + 2 mm)
= 11.083 mm

Next available standard thickness is $\boxed{12 \text{ mm}}$.