Assigment - 1

8) A process vessel is to be designed for maximum operating pressure of 800 kPa. The vessel has a nominal diameter (O.D.) of 1.5 m. It is made of IS : 2002 - 1962 grade 2B quality steel having allowable design stress of 120 MPa, at working temperature. Use weld joint efficiency as 0.85

(i) Find standard thickness of plate to fabricate this vessel.

(ii) Find out thickness of flat head (head is flanged and butt welded to shell)

(iii) Find out thickness of a conical head having apex angle of 45°

(iv) Find out thickness of plate required to fabricate a torispherical head for this vessel. It is assumed that there is no uncompensated opening in the head. Specifications of the head are :

$R_i = D_o$; $r_i = 0.05 D_o$; $S_f = 30$ mm

(v) Find out thickness of a standard 2:1 ellipsoidal head.

(vi) Find out thickness of hemispherical head.

Determine which head thickness is minimum

A) P_d (Design Pressure) = 0.D + 5% extra

$$P_d = 1.05 \times 800 \times 1000$$
$$= 840 \text{ kPa}$$

$D_o = 1.5\text{m}$, $J = 0.85$

$f = 120 \times 10^6$ Pa (Allowable Design Stress)

(i) Minimum wall thickness without corrosion allowance

$$t = \frac{P_d D_o}{2fJ + P}$$

$$= \frac{840 \times 10^3 \times 1.5}{2 \times 120 \times 10^6 \times 0.85 + 840 \times 10^3}$$

$$= 6.151 \times 10^{-3} \text{ m}$$

$\therefore t = 6.151$ mm

Considering corrosion allowance for carbon steel to be 2mm

$ca = 2$mm

$t' = t + ca$

$= 2 + 6.151$

$\therefore t' = 8.151$ mm

Standard thickness available (near highest) is 9mm

Hence, so as to fabricate the vessel we use thickness of 9mm

(ii) Thickness of flat head (Head is flanged and butt welded to shell)

$\Rightarrow C = 0.45$

$$\text{Thickness } (t) = C D_o \sqrt{\frac{P}{f}}$$

$$D_o = D_i - 2t'$$
$$= 1.5 - 2(9 \times 10^{-3})$$
$$= 1.482 \text{ m}$$
$$= 1482 \text{ mm}$$

$$t = 0.45 \times 1482 \sqrt{\frac{840 \times 10^3}{120 \times 10^6}} = 55.796 \text{ mm}$$

Considering corrosion allowance

Thickness = (55.796 + 2) mm
= 57.696 mm

Final thickness considering of 6% safety of measure

$$t' = (1.06)(57.896)$$
$$= 61.26 \text{ mm}$$

∴ Standard available thickness (near highest) is 63 mm

(iii) Thickness of conical head

a) Thickness of head at function of head and shell

$$t = \frac{PD_e Z}{2fJ}$$

Given apex angle (α) = 45° ⇒ Z = 2.05

$f = 120 \times 10^6$ Pa P = 840 kPa

J = 0.85 D_e = 1481 mm

$$\therefore t = \frac{840 \times 10^3 \times 1482 \times 2.05 \times 10^{-3}}{2 \times 120 \times 10^6 \times 0.85}$$
$$= 12.51 \text{ mm}$$

Corrossion allweance $t_a' = t + c = 12.51 + 2\text{mm}$

$= 14.51$ mm

Standard thickness near highest aviatable is 16 mm

b) Thickness away from junction

$$t = \frac{PD_k}{2fJ - P} \times \frac{1}{\cos\alpha}$$

where D_k is maximum inside diameter of cone at a distance $\frac{1}{2}\left(\frac{D_o t}{\cos\alpha}\right)^{1/2}$

$$= \frac{1}{2}\left(\frac{1500 \times 16}{\cos(45^\circ)}\right)^{1/2}$$

$$= 92.12 \text{ mm}$$

$$D_e = 1500 - 2\times16 - 2 \times 92.12 \cos(45^\circ)$$

$$= 1337.72 \text{ mm}$$

$$t = \frac{0.840 \times 1337.72}{2 \times 120 \times 0.85 - 0.84} \times \frac{1}{0.707} \text{ mm}$$

$$= 7.822 \text{ mm}$$

Corrosion Allowance $t_a' = 2\text{mm} + t$

$$= (7.822 + 2) \text{ mm}$$

$$= 9.822 \text{ mm}$$

∴ Thickness of conical head to be used is 16 mm as that is the max of two.

(vi) Thickness of hemispherical head

$$t = \frac{p D_o C}{2 f J}$$

From the geometry of hemisphere, we see that $\frac{he}{D_o} = 0.5$, hence $C = 0.55$

$$t = \frac{0.84 \times 1500 \times 0.55}{2 \times 120 \times 0.85}$$

$$= 3.397 \text{ mm}$$

Corrosion allowance $ta' = (2 + t)$ mm

$= 5.397$ mm

Final thickness considering of 6% safety of measure

$t' = (1.06)\ 5.397$

$= 5.72$ mm

Standard thickness near highest available = 6 mm

(v) Thickness of a standard 2:1 ellipsoidal head.

$\therefore \quad he/D_o = 0.25$

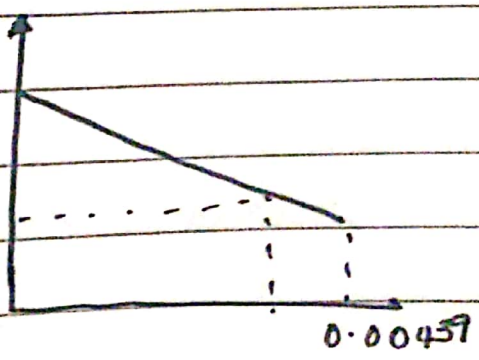
$$\frac{t}{D_o C} = \frac{P}{2fJ} = \frac{840 \times 10^3}{2 \times 120 \times 10^6 \times 0.85}$$

$$= 0.00411$$

For $\frac{t}{D_o} = 0.002 \Rightarrow \frac{t}{D_o C} = \frac{0.002}{1.38} = 0.00145$

For $\frac{t}{D_o} = 0.005 \Rightarrow \frac{t}{D_o C} = \frac{0.005}{1.14} = 0.0439$

Interpolating for $\frac{t}{D_o C} = 0.00411$,



$y = mx + c'$

$$\frac{y_2 - y_1}{x_2 - x_1} = -81.6326$$

$c' = 1.38 - m(0.00145)$

$= 1.498$

$y = (-81.6326)x + 1.498$

∴ The C value for $\frac{t}{D_o C} = 0.00411$ is

$$C = (-81.6326) \times 0.00411 + 1.14$$
$$= 1.162$$

$$t = \frac{D_o C P}{2 f J}$$

$$= \frac{840 \times 10^3 \times 1500 \times 1.162}{2 \times 120 \times 10^6 \times 0.85}$$

$$= 7.1771 \text{ mm}$$

Corrosion allowance $t_a' = 9.177 \text{mm}$

Final thickness considering of 6% safety of measure

$$t' = (1.06)\ 9.177$$
$$= 9.727 \text{ mm}$$

Standard thickness near highest available is 10 mm

(iv) Thickness using Torospherical Head

$R_i = D_o$ $\quad r_i = 0.05 D_o$ $\quad S_f = 30\ mm$

$R_o = D_o = 1.5\ m$ $\quad r_o = 0.05 D_o = 0.75\ m$

$S_f = 30\ mm$

$$h_o = R_o - \left[\left(R_o - \frac{D_o}{2}\right) \times \left(R_o + \frac{D_o}{2} - 2r_o\right)\right]^{\frac{1}{2}}$$

$$= 1.5 - \sqrt{1.4625}$$

$$= 1.5 - 1.209$$

$$= 0.291\ m$$

$$\frac{D_o^2}{4R_o} = \frac{1.5^2}{4 \times 1.5} = 0.375\ m$$

$$\sqrt{\frac{D_o r_o}{2}} = \sqrt{\frac{1.5 \times 0.075}{2}} = 0.237\ m$$

$$h_e = \min\left[h_o, \frac{D_o^2}{4R_o}, \sqrt{\frac{D_o r_o}{2}}\right]$$

$$= 0.237\ m$$

$$\frac{h_e}{D_o} = \frac{0.237}{1.5} = 0.158\ m \approx 0.16\ m$$

$$\frac{t}{D_o C} = \frac{P}{2fJ} = \frac{0.84}{2 \times 120 \times 0.85} = 0.0041$$

h_e / D_o	0.002	0.005	0.01	0.02	0.04
0.15	4.55	2.66	2.15	1.95	1.75
0.16	4.19	2.468	2.01	1.842	1.664
0.20	2.3	1.7	1.45	1.37	1.32

↑ By Interpolation

Interpolation

t/D_o	C	
$\frac{0.002}{4.19}$ =	0.0004	4.19
0.002 =	$\frac{0.005}{2.5}$	2.5
0.0049 =	$\frac{0.01}{2.04}$	2.039

} Using Interpolation

$\therefore C = 2.143$

$$t = \frac{PD_oC}{2fJ} = \frac{840 \times 10^3 \times 2.143}{2 \times 120 \times 10^6 \times 0.85}$$

$$= 13.89 \text{ mm}$$

Corrosion allowance = (2+b) mm

= 15.89 mm

Considering 6% safety of measure,

final thickness = 16.84 mm

Standard thickness (near highest) available is 18 mm

Head	Minimum Thickness
Flat	63 mm
Conical Head ($\alpha = 45^\circ$)	16 mm
Hemispherical	6 mm
Torispherical Head (with give specifications)	18 mm
2:1 Ellipsoidal Head	10 mm
Pressure vessel	9 mm

Minimum thickness is for hemisphere and its value is 6mm