Design of Flanges

① Design Pressure (P_d) = 2.5 MPa
Design Temperature (T_d) = 200°C

Given that asbestos with 1.6 mm thickness is used as gasket material

Shell I.D = 1.5 m
Allowable stress for shell and flange material = 100 MPa
Allowable stress for bolting material = 138 MPa

Hub Thickness = 12 mm
Weld joint efficiency (J) = 0.85

Distance between gasket and outer shell surface = 6 mm
m = 2.75, y = 25.5 MPa

$$\frac{d_o}{d_i} = \sqrt{\frac{25.5 - 2.5 \times 2.75}{25.5 - 2.5 \times (2.75 + 1)}} = 1.0757$$

Shell thickness $(g_o) = \frac{p D_o}{2fJ + p}$

$$g_o = \frac{2.5\,(1.5 + 0.002 + g_o)}{2 \times 100 \times 0.85 + 2.5}$$

$$172.5\, g_o = 3.755 + 2.5 g_o$$

$$g_o = \frac{3.755}{170} = 0.02208 \text{ m}$$

$$\therefore\ g_o \approx 0.022 \text{ m}$$

$$g = g_o + \underbrace{t_c}_{\text{Corrosion Allowance}} = 0.022 + 0.002$$

$$\therefore\ g = 0.024 \text{ m}$$

Standard thickness (near highest) available is 0.025m (25 mm)

Shell O.D = Shell I.D + 2 (Shell thickness)

$$= 1.5 + 2(0.025)$$

$$= 1.55 \text{ m}$$

Gasket inner Diameter, $d_i = 1.55 + 2(0.006)$

$$= 1.562 \text{ m}$$

$\therefore$ Gasket is placed 6mm from outer surface

$$\frac{d_o}{d_i} = 1.0747$$

$$\Rightarrow d_o = 1.0747 \times 1.562$$
$$= 1.6787 \text{ m}$$

Min gasket width $= \frac{d_o - d_i}{2}$

$$= \frac{1.6787 - 1.562}{2}$$

$$= 0.0583 \text{ m}$$

$$b_o = \frac{0.0583}{2} = 0.02917 \text{ m}$$

Since b_o (29 mm) > 6.3 mm

$$b = 2.5 (b_o)^{1/2} = 2.5\sqrt{29.17} = 13.5 \text{ mm}$$

Also, $G = (d_o - 2b)$
$$= (1.6787 - 2 \times 0.0135)$$
$$= 1.6517 \text{m}$$

Bold load due to design pressure $= \frac{\pi G_i^2 P}{4}$

$= 5.352 \text{ MPa } m^2$

$= 5.352 \text{ MN}$

Bolt load for adequate compression $= 2\pi G b m p$

$= 2 \times \pi \times 1.6517 \times 0.0135 \times 2.75 \times 2.5$

$= 0.963 \text{ MN}$

Total operating load $= 5.352 + 0.963$

$= 6.315 \text{ MN} \quad (W_o)$

Bolt load under bolting up condition

$= \pi G b y \quad (W_g)$

$= \pi \times 1.6517 \times 0.0135 \times 25.5$

$= 1.756 \text{ MN}$

Minimum bolting area $= \frac{W_o}{S_o}$

$S_o \rightarrow$ Allowable stress at design temp.

$S_o = 138 \text{ MPa}$ (given)

Min bolting area $= \frac{6.315}{138} = 0.04576 \text{ m}^2$

Selection of bolt :

If bolt is $Ma \times b$ (dimensions)

Root area = $\frac{\pi}{4}(a - b^2)^2 \times 10^{-6}\ m^2$

n (no. of bolts) = $\frac{\text{Bolting Area}}{\text{Root Area}}$

Actual n = multiple of 4 just greater than

$$\left.\begin{aligned} C_1 &= B + 2(g_1 + R) \\ C_2 &= nB_s/\pi \end{aligned}\right\} \rightarrow (1)$$

C_1 and C_2 should be as close as possible

(i) M 18 x 2 : root area $(A_r) = \frac{\pi}{4}(18 - 2\times2)^2 \times 10^{-6}$

$= 0.15394 \times 10^{-3}\ m^2$

$n = \frac{0.04576}{0.15394} \times 10^3 = 297$

Actual n = 300

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From (1),

$c_1 = 1.55 + 2(0.012 + 0.027) = 1.628\ m$

$c_2 = 300 \times 0.075/\pi = 7.16\ m$

(ii) M 20x2 : $A_r = 0.201 \times 10^{-3}\ m^2$

$n = 227.66 \Rightarrow n = 228$

$c_1 = 1.55 + 2(0.012 + 0.03) = 1.634\ m$

$c_2 = 228 \times 0.075/\pi = 5.44\ m$

Similarly,

(iii) M 22x2 : $c_1 = 1.64\ m$ $c_2 = 4.297\ m$

(iv) M 24x2 : $c_1 = 1.644\ m$ $c_2 = 3.53\ m$

(v) M 27x2 : $c_1 = 1.65\ m$ $c_2 = 2.67\ m$

(vi) M 30x2 : $c_1 = 1.662\ m$ $c_2 = 2.1\ m$

(vii) M 33x2 : $c_1 = 1.668\ m$ $c_2 = 1.666\ m$

(viii) M 36x3 : $c_1 = 1.674\ m$ $c_2 = 1.62\ m$

(ix) M 39x3 : $c_1 = 1.678\ m$ $c_2 = 1.53\ m$

(x) M 42x3 : $c_1 = 1.684\ m$ $c_2 = 1.27\ m$

$\therefore$ We select M 33x2 : Bolt circle diameter $= c_1 = 1.668\ m$

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$\therefore$ No. of bolts $= \dfrac{0.04576 \times 10^6}{\frac{\pi}{4}(33-2\times2)^2}$

$= 68$ bolts

Flange OD $= G + \text{bolt dia} + t_c$ Corrosion allowance

$= 1.668 + 0.033 + 0.02$

$= 1.721$ m

Gasket Inner Diameter	=	1.562 m
Gasket Outer Diameter	=	1.6517 m
Gasket Width	=	0.0583 m
Bolt circle diameter	=	1.668 m
No. of bolts	=	68 bolts
Flange OD	=	1.721 m

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