Lecture 3: Design Components

2.3.8. Gaskets

Gaskets are used to make the metaltometal surfaces leak-proof. Gaskets are elasto-plastic materials and relatively softer than the flange materials. Deformation of gaskets under load seals the surface irregularities between metal to metal surfaces and prevents leakage of the fluid.For design pressures<16 kgf/cm^2 and when there is no contact with oil or oil vapor, the compressed asbestos fiber, natural or synthetic rubber or other suitable gasket and packing materials having the appropriate mechanical and corrosion resisting properties may be used (IS:4503).

A preliminary estimation of gaskets is done using following expression:

$Residual\ gasket\ force\ = (Gasket\ seating\ force)$– $(Hydrostatic\ pressure\ force)$

The residual gasket force should be greater than that required to prevent the leakage of the internal fluid. This condition results the final expression in the form of:

$$\frac{D_{OG}}{D_{IG}} = \sqrt{\frac{Y-pm}{Y-p(m+1)}} \qquad (2.10)$$

D_{OG}=outside gasket diameter [mm]

D_{IG}=inside gasket diameter [mm]; usually, D_{IG}=D_s+0.25

p=design pressure

Y= minimum design seating stress (**Table 2.4**)

m= gasket factor (**Table 2.4**)

Calculate the width of the gasket width, $N = (D_{OG} - D_{IG})/2$ (2.11)

[**The IS:4503 specifies that the minimum width of peripheral ring gaskets for external joints shall be 10 mm for shell sizes up to 600 mm nominal diameter and 13 mm for all larger shell sizes**]

Table 2.4. Gasket factors and minimum gasket seating force [4].

Gasket materials		Gasket factor (m)	Maximum design seating stress (Y), kgf/mm^2
Flat metal jacketed, asbestos fill	Soft Al	3.25	3.87
	Soft Cu or brass	3.50	4.57
	Iron or soft steel	3.75	5.35
	Monel	3.50	5.62
	Chrome 4-6%	3.75	6.33
	Stainless steel	3.75	6.33
Solid flat metal	Soft Al	4.00	6.19
	Soft Cu or brass	4.75	9.14
	Iron or soft steel	5.50	12.65
	Monel	6.00	15.32
	Chrome 4-6%	6.00	15.32
	Stainless steel	6.50	18.28
Corrugated metal with asbestos fill	Soft Al	2.50	2.04
	Soft Cu or brass	2.75	2.60
	Iron or soft steel	3.00	3.16
	Monel	3.00	3.87
	Chrome 4-6%	3.25	3.87
	Stainless steel	3.50	4.57

2.3.9. Bolts design

The bolt design procedure is as follows:

The minimum initial bolt load (W_{m1}) at atmospheric pressure and temperature is given by:

$$W_{m1} = \pi b G Y \tag{2.12}$$

The gasket is compressed under tight pressure. The required bolt load (W_{m2}) is given by:

$$W_{m2} = H + H_P = 2\pi b G m p + \frac{\pi}{4} G^2 p \tag{2.13}$$

Where, mean gasket diameter, $G = \frac{D_{OG} + D_{IG}}{2}$ (2.14)

Total hydrostatic end force, $H = \frac{\pi}{4} G^2 p$ (2.15)

Total joint contact surface compression load, $H_P = 2\pi b G m p$ (2.16)

Effective gasket seating width, b=b_o for $b_o < \frac{1}{4}$inch (6 mm) and b=$0.5\sqrt{b_o}$ for $b_o > \frac{1}{4}$inch (6 mm)

Basic gasket seating width $b_o = N/2$ for flat flange (2.17)

Determine the controlling load: the greater value ofW_{m2}orW_{m1}

Calculate the **required (minimum) bolt crosssectional area**, $A_m$based on the controlling load:

$A_m = \frac{W_{m2}}{f_b}\ or\ \frac{W_{m1}}{f_a}$ (2.18)

f_b= allowable bolt stress at design temperature, f_a= allowable bolt stress at ambient temperature

Select the number ofbolts (usually a multiple of 4 is used), bolt circle diameter (C_b), root diameter (d_{br}) and bolt edge distance (E)(follow IS: 4864-1968, to select bolts details).

From the number ofbolts chosen, find out the **actual bolt area (A_b). AlwaysA_b should be greaterthan A_m**.

Check for the minimum gasket width, $N_{min} = \frac{A_b f_b}{2\pi YG}$ (2.19)

Nshould be greater thanN_{min} .

2.3.10. Design of flange

Calculation of flange forces:

Hydrostatic end force on area inside of the flange is given, $H_D = \frac{\pi B^2 p}{4}$ (2.20)

Where, B is the centre line to centre line bolt-spacing can be taken same as outside shell diameter)

Pressure force on the flange face, $H_T = H - H_D$ (2.21)

Gasket load under operating conditions, $H_G = W - H$ (2.22)

For gasket seating condition, $H_G = W$ (2.23)

Calculation of flange moment:

Calculate the summation of flange moments for the operating condition,

$M_f = M_D + M_T + M_G$ (2.24)

Moment due toH_D,$M_D = H_D h_D$; where $h_D = (C_b - B)/2$ (2.25)

Moment due to H_T,$M_T = H_T h_T$; where $h_T = (h_D + h_G)/2$ (2.26)

Moment due to H_G,$M_G = H_G h_G$; where $h_G = (C_b - G)/2$ (2.27)

The flange bolt load, $W = \frac{(A_m + A_b) f_a}{2}$ for gasket seating condition and, (2.28)

$W = W_{m2}$forthe operating condition (2.29)

Calculate the flange moment for the gasket seating condition: $M_f^o = \frac{W(C_b - G)}{2}$ (2.30)

Calculate the flange thickness (t_f) based on the maximum value for the gasket seating condition or operating condition given by:

$$t_f = \sqrt{\frac{M_f Y}{f_f B}} \; or \; \sqrt{\frac{M_f^o Y}{f_{fa} B}}$$ which one is greater (2.31)

f_f = allowable flange stress at design temperature, f_{fa} = allowable flange stress at ambient temperature.

You can determine Y as a function of K. The value K is available in standard pressure vessel design book. You may find from reference **[4]** (page 238, Figure 12.22).

$K = \frac{A}{B}$; where flange OD, A =bolt circle (C_b) diameter + $2E$

[The standards of flanges, gaskets, and flange faces design are given in IS: 4864-1968 to IS: 4870-1968]

2.3.11. Design of supports

The selection of the type of support for a pressure vessel depends on various parameters like the vessel elevation from the ground, materials of construction, wall thickness, operating temperature, external loads (such as wind loads, seismic condition etc).Supports for The vertical pressure vessels units are supported generally by i). skirt supports, ii). ring supports and iii).lug supports. Whereas, the horizontal pressure vessels are supported by i). saddle supports, ii). leg supports and iii). ring supports. Saddle supports are widely used in horizontal heat exchanger units.

IS:4503 specifies that the horizontal heat exchanger units shall be provided with at least two supporting saddles with holes for anchor bolts. The holes in at least one of the supports shall be elongated to provide for expansion of the shell. The vertical units shall be provided with at least two supports of sufficient size to carry the unit in a supporting structure of sufficient width to clear shell flanges.