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Basis for calculation of aluminium alloy pipe flanges

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Foreword

This translation has been made based on the original Japanese Industrial Standard revised by the Minister of International Trade and Industry through deliberations at Japanese Industrial Standards Committee in accordance with the Industrial Standardization Law:

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Basis for calculation of aluminium alloy pipe flanges

1 Scope This Japanese Industrial Standard specifies the basis for stress calculation of a bolt-fastening circular flange (hereafter referred to as “flange”) which uses a ring-type gasket made of aluminium and aluminium alloy, the basis for calculation of total load (hereafter referred to as “gasket reaction force”) working on gasket surface when inside pressure is applied, and the basis for calculation of required gasket reaction force when design pressure is acting.

Remarks 1 In this Standard, the load used for calculation shall be the load working on the flange when the gasket is fastened and when inside pressure applies. Therefore, the following loads are not taken into account.

- (1) Compulsory force resulted when flange is mounted.
 - (2) Outside force transmitted from the connecting piping system while being used.
 - (3) Thermal stress generated inside the flange while being used.
 - (4) Stress generated owing to the difference of thermal expansion occurring between a flange and bolts while being used.
- 2** In either case where the gasket is fastened and inside pressure works, if flange surfaces contact each other at outside the center circle by bolt holes, this Standard is not applicable.
- 3** The units and numerical values given in { } in this Standard are based on the traditional units and are appended for informative reference.

2 Symbols

2.1 The symbols used in 3 and 4 shall be as follows.

A : outside diameter of flange (mm). When bolt hole notches to the outside diameter of flange, it shall be the diameter of the circle inscribing the notch.

A_b : $n \frac{\pi}{4} d_b^2$, total effective sectional area of bolts that are practically employed (mm²)

A_m : required total effective sectional area (mm²) of bolts, A_{m1} or A_{m2} , whichever is larger.

A_{m1} : required total effective sectional area of bolts under use (mm²)

A_{m2} : required total effective sectional area of bolts when gasket is fastened (mm²)

B : inner diameter of flange (mm). When axial stress σ_H is calculated, if B is smaller than $20g_1$, B_1 can be used instead of B .

B_1 : $B + g_0$ (mm) (applicable to a solid flange where $f \geq 1$)

B_1 : $B + g_1$ (mm) (applicable to a loose flange or to a solid flange where $f < 1$.
Provided that the minimum value of f is 1.)

b : effective width of gasket seating (mm), and it is as follows.

When $b_0 \leq 6.35$ mm, $b = b_0$

When $b_0 > 6.35$ mm, $b = 2.52 \sqrt{b_0}$

b_0 : basic width (mm) of gasket seating, and it follows Attached Table 2.

C : diameter of center circle by bolt holes (mm)

c : basic dimension (mm) for the minimum weld dimension, t_n or t_1 , whichever is smaller.

D_g : outside diameter of gasket (mm)

d : factor, for solid flange and optional flange to be calculated as solid flange,
it is $\frac{U}{V} h_0 g_0^2$, and for loose flange, it is $\frac{U}{V_L} h_0 g_0^2$.

d_b : minor diameter of screw thread of bolt or the minimum part of diameter
at shank of a bolt (mm), whichever is smaller.

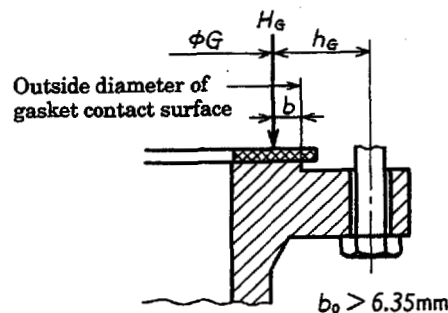
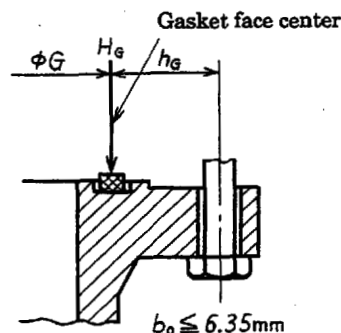
e : factor, for solid flange and optional flange to be calculated as solid flange,
it is $\frac{F}{h_0}$, and for loose flange, it is $\frac{F_L}{h_0}$.

F : factor of solid flange and optional flange to be calculated as solid flange,
and it follows Attached Fig. 2 or Attached Table 3.

F_L : factor of loose flange, and it follows Attached Fig. 3 or Attached Table 3.

f : correction factor of hub stress, and it follows Attached Fig. 1 or Attached
Table 3. (When $f > 1$, f expresses the ratio of the stress on part of hub
with thickness g_0 to the stress on part of hub with thickness g_1 . When
 $f < 1$, take it as $f = 1$.)

G : diameter of the circle made by gasket reaction force (mm)



When $b_0 \leq 6.35$ mm, G = diameter of center circle on gasket surface

When $b_0 > 6.35$ mm, G = (outside diameter of gasket contact surface)
- $2b$

In the case of lap joint type flange, it conforms to Fig. (a) of 3.

g_1 : thickness of hub at back of flange (mm)

g_0 : thickness of hub tip (mm)

H : $\frac{\pi}{4} G^2 P \left\{ \frac{\pi}{400} G^2 P \right\}$, total load applied to flange by inside pressure (N {kgf})

H_D : $\frac{\pi}{4} B^2 P \left\{ \frac{\pi}{400} B^2 P \right\}$, load applied to inside diameter surface of flange by inside pressure (N {kgf})

H_G : $W_0 - H$, gasket load (N {kgf}), that is, the difference between the bolt load and total load acting on the flange by inside pressure

H_P : $2\pi b G m P \left\{ \frac{2\pi b}{100} G m P \right\}$, compression force applied to gasket or to joint contact surface in order to keep airtightness sufficiently (N {kgf})

H_T : $H - H_D$, difference between total load applied to flange by inside pressure and the load applied to inside diameter surface of flange (N {kgf})

h : length of hub (mm), and it follows Fig. 1 of 3.

h_D : distance (mm) toward radius from center circle by bolt holes to H_D action point, and it follows Table 1 of 4.2.

h_G : distance (mm) toward radius from center circle by bolt holes to H_G action point, and it follows Table 1 of 4.2.

h_T : distance (mm) toward radius from center circle by bolt holes to H_T action point, and it follows Table 1 of 4.2.

h_0 : $\sqrt{B g_0}$ (mm)

K : factor, $\frac{A}{B}$

L : factor, $\frac{te+1}{T} + \frac{t^3}{d}$

M : moment (N·mm {kgf·mm}) acting on flange, and it is as follows.

(1) under use $M = M_0$

(2) when gasket is fastened $M = M_g$

M_D : $H_D h_D$, moment by the load applying to inside diameter surface of flange by inside pressure (N·mm {kgf·mm})

M_G : $H_G h_G$, moment by gasket load (that is, the moment caused by difference between load on bolts of flange and total load on flange by inside pressure) (N·mm {kgf·mm})

M_T : $H_T h_T$, moment caused by difference between total load applying to flange by inside pressure and load applying to inside diameter surface of flange (N·mm {kgf·mm})

M_g : moment acting on the flange when gasket is fastened (N·mm {kgf·mm})

M_0 : total moment acting on flange under use (N·mm {kgf·mm})

- m : factor of gasket, and it follows Attached Table 1.
- N : width (mm) of gasket contact surface, and it follows Attached Table 2.
- n : number of bolts
- P : inside pressure (MPa {kgf/cm²})
- P_e : outside pressure (MPa {kgf/cm²})
- R : $\frac{C-B}{2} - g_1$, distance toward radius from center circle by bolts to intersecting point of hub and back of flange (mm)
- r : radius of corner (mm), and it is at least $0.25g_1$, provided that it shall be 4.5 mm or more.
- T : factor determined by the value of $K\left(=\frac{A}{B}\right)$, and it follows Attached Fig. 4.
- t : thickness (mm) of flange, excluding the height of gasket bearing surface and depth of gasket groove
- t_n : thickness of connecting pipe (mm)
- t_1 : when calculating as solid flange, it is $2g_0$, and when calculating as loose flange, it is twice the thickness of connecting pipe required for calculation to inside pressure (mm). Provided that it shall be 6.35 mm or over.
- U : factor determined by the value of $K\left(=\frac{A}{B}\right)$, and it follows Attached Fig. 4.
- V : factor for solid flange or optional flange to be calculated as solid flange, and it follows Attached Fig. 5 or Attached Table 3.
- V_L : factor for loose flange, and it follows Attached Fig. 6 or Attached Table 3.
- W_0 : bolt load under use (N {kgf})
- W_g : bolt load when gasket is fastened (N {kgf})
- W_{m1} : the minimum bolt load required under use (N {kgf})
- W_{m2} : the minimum bolt load required when gasket is fastened (N {kgf})
- Y : factor determined by the value of $K\left(=\frac{A}{B}\right)$, and it follows Attached Fig. 4.
- y : the minimum designed fastening pressure (N/mm² {kgf/mm²}) on contact surface of gasket or joint, and it follows Attached Table 1.
- Z : factor determined by the value of $K\left(=\frac{A}{B}\right)$, and it follows Attached Fig. 4.
- σ_H : axial stress of hub (N/mm² {kgf/mm²})
- σ_R : radial stress of flange (N/mm² {kgf/mm²})
- σ_T : circumferential stress of flange (N/mm² {kgf/mm²})
- σ_a : tolerable tensile stress of material of bolt at ordinary temperature (N/mm² {kgf/mm²})

σ_b : tolerable tensile stress of material of bolt at the temperature under use (N/mm² {kgf/mm²})

σ_f : tolerable tensile stress of material of flange at the temperature under use (N/mm² {kgf/mm²})

Furthermore, when gasket is fastened, it is tolerable tensile stress at ordinary temperature (N/mm² {kgf/mm²}).

σ_n : tolerable tensile stress of material of pipe or pipe-shaped part at the temperature under use (N/mm² {kgf/mm²})

Furthermore, when gasket is fastened, it is tolerable tensile stress at ordinary temperature (N/mm² {kgf/mm²}).

2.2 The symbols to be used in 5 and 6 shall be in accordance with 2.1 and with the following.

A_g : contact area of gasket and bearing surface of flange (mm²)

C_0 : diameter at center of flange ring figure (mm)

E_b : Young's modulus of bolt material at ordinary temperature (N/mm² {kgf/mm²})

E_f : Young's modulus of flange ring material at ordinary temperature (N/mm² {kgf/mm²})

E_g : Young's modulus of gasket when being recovered at ordinary temperature (N/mm² {kgf/mm²})

E_h : Young's modulus of hub material at ordinary temperature (N/mm² {kgf/mm²})

E_0 : Young's modulus of connecting pipe material at ordinary temperature (N/mm² {kgf/mm²})

f_h : height of flange bearing surface (mm)

g_h : average thickness of hub (mm)

H_p' : required gasket reaction force (N {kgf})

l_{ob} : length of bolt deformation range (mm)

$$l_{ob} = 2(t + f_h) + t_g$$

m' : corrected gasket factor

t_g : thickness of gasket (mm)

W_g' : gasket reaction force under use (N {kgf})

W_{m1}' : actual load on bolt under use (N {kgf})

θ^0 : rotation angle of flange ring by fastening stress of gasket (rad)

θ^p : rotation angle of flange ring under use (rad)

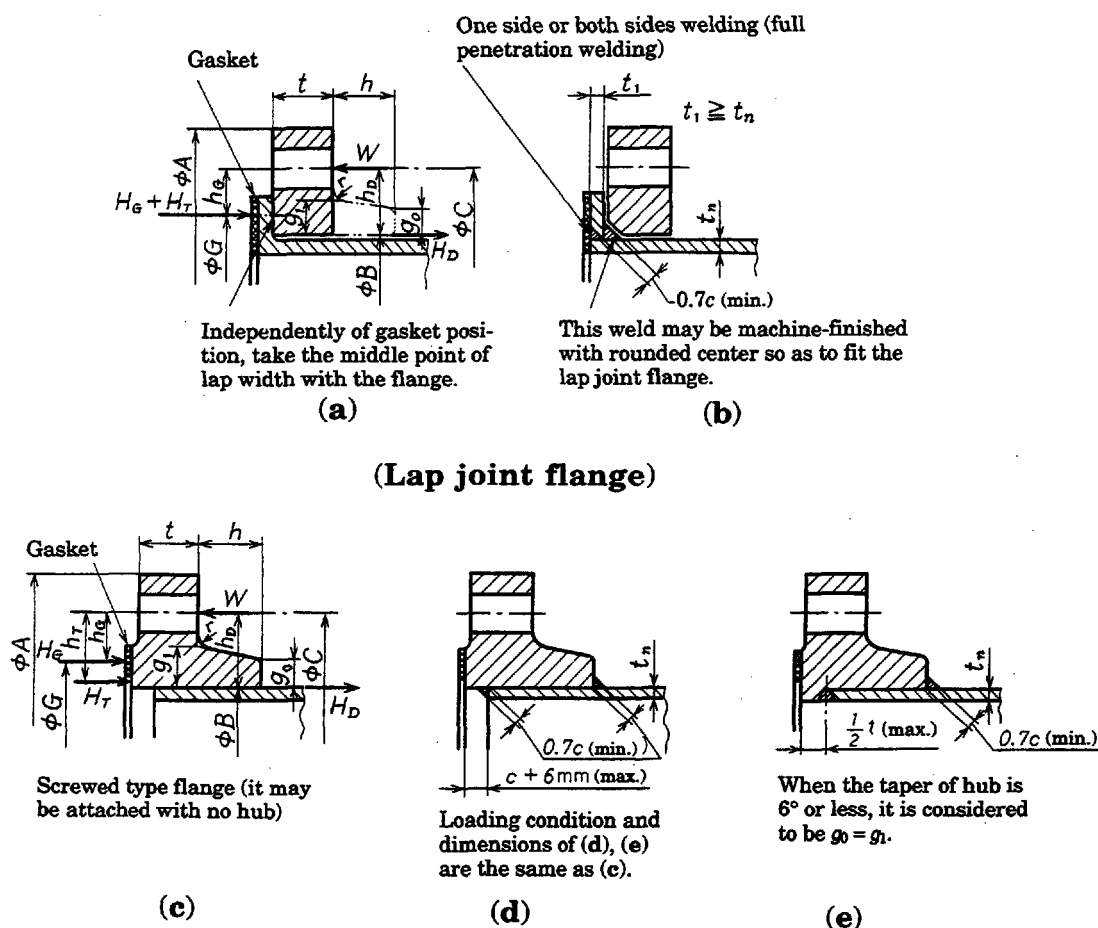
ν : Poisson's ratio (connecting pipe material, hub material, flange ring material), and take it as $\nu = 0.3$.

3 Types of flanges The types of flanges taken up here shall be as follows.

(1) Loose flange

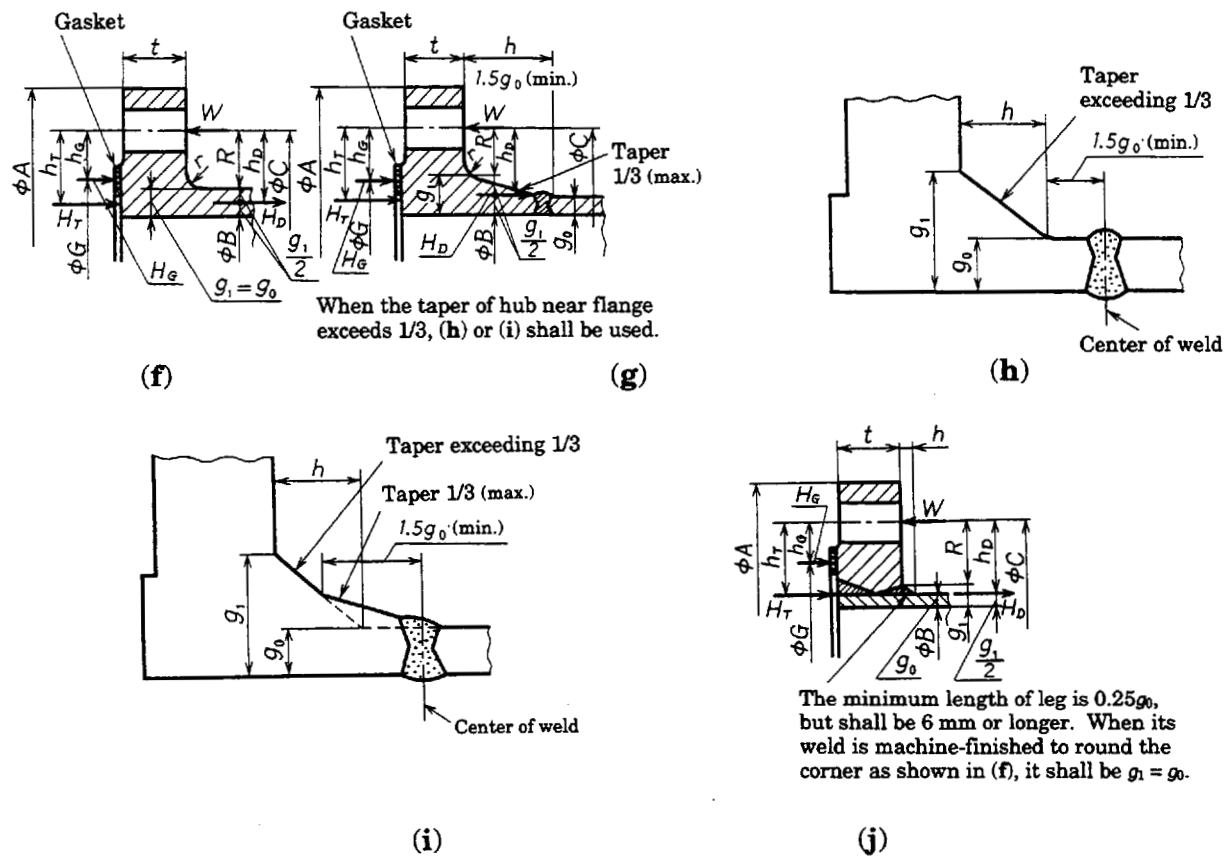
- (a) Lap joint flange [Fig. 1 (a), (b)] The flange to be used in combination of stub joint.
 - (b) Slip-on flange [Fig. 1 (c), (d), (e)] The flange is screwed in or slipped on pipe, and is attached as shown in Fig. 1 (d), (e) by welding.
- (2) Solid flange [Fig. 1 (f), (g), (h), (i), (j)] The flange and pipe are casted or forged into one body, otherwise as shown in Fig. 1 (g) to Fig. 1 (j), flange and pipe are welded with full penetration into one body.
- (3) Optional flange [Fig. 1 (k), (l), (m), (n), (o)] As shown in Fig. 1 (k) to Fig. 1 (o), flange is attached to pipe by welding. This type of flange shall be treated as one solid flange for calculation. When every following item does not exceed indicated value respectively, however, for simplifying, it may be calculated as loose flange without a hub.

$$g_0 = 16 \text{ mm}, \quad \frac{B}{g_0} = 300, \quad P = 2 \text{ MPa } \{20 \text{ kgf/cm}^2\}$$

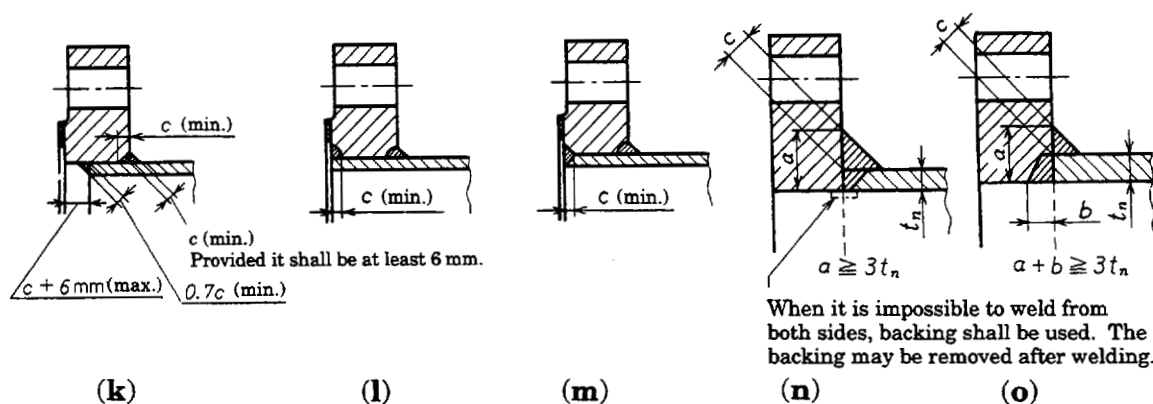


(1) Loose flange (Slip-on flange)

Fig. 1 Type of flanges



(2) Solid flange



(3) Optional flange

Fig. 1 (concluded)

4 Calculation of stress on flange Carry out the stress calculation for general flange in accordance with 4.1 to 4.3, that for flange exposed to outside pressure in accordance with 4.4, and that for split flange in accordance with 4.5.

4.1 Bolt load The bolt load shall be calculated as follows.

- (1) **Bolt load required for calculation** The bolt load employed for the calculation of required total effective sectional area of a bolt shall be obtained as follows.

(a) **Bolt load required under use**

$$W_{m1} = H + H_p = \frac{\pi}{4} G^2 P + 2\pi b G m P = \frac{\pi G P}{4} (G + 8bm)$$

$$\left\{ W_{m1} = H + H_p = \frac{\pi}{400} G^2 P + \frac{2\pi b}{200} G m P = \frac{\pi G P}{400} (G + 8bm) \right\}$$

(b) **Bolt load required when gasket is fastened**

$$W_{m2} = \pi b G y$$

- (c) **Bolt load required when self-seal gasket is used** In this calculation, except the special shaped flange which axial load for fastening can not be neglected, the following formulae may be used.

$$W_{m1} = H = \frac{\pi}{4} D_g^2 P \left\{ W_{m1} = H = \frac{\pi}{400} D_g^2 P \right\}$$

$$W_{m2} = 0$$

- (2) **Required total effective sectional area of bolt and total effective sectional area of bolt practically used** Total effective sectional area of bolt A_m , required when it is under use and when gasket is fastened, shall be the value calculated by the following formulae, whichever is larger.

$$A_{m1} = \frac{W_{m1}}{\sigma_b}$$

$$A_{m2} = \frac{W_{m2}}{\sigma_a}$$

The bolts to be practically used shall be so chosen that their total effective sectional area A_b is larger than the required total effective sectional area of bolts A_m .

- (3) **Bolt load to be used for calculation of flange** The bolt load to be used for calculation of flange shall be as follows.

(a) **Bolt load under use**

$$W_0 = W_{m1}$$

(b) **Bolt load when gasket is fastened**

$$W_g = \frac{A_m + A_b}{2} \sigma_a$$

Remarks : In either case where safety against over-fastening is excessively required or flange is required to resist the effective total bolt load $A_b \times \sigma_a$, the flange may be calculated on the basis of bolt load shown when gasket is fastened.

4.2 **Moment acting on flange** The moment acting on flange shall be as follows.

- (1) **Total moment acting on flange under use** The total moment acting on a flange under use shall be as follows.

$$M_0 = M_D + M_G + M_T$$