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Prirobnice in prirobnični spoji - Pravila za konstruiranje okroglih prirobničnih spojev s tesnili - 5. del: Metoda izračuna prirobničnih spojev z ravno tesnilno površino

Flanges and their joints - Design rules for gasketed circular flange connections - Part 5: Calculation method for full face gasketed joints

Flansche und ihre Verbindungen - Regeln für die Auslegung von Flanschverbindungen mit runden Flanschen und Dichtung - Teil 5: Berechnungsmethode für Verbindungen mit vollflächiger Dichtung

Brides et leurs assemblages - Règles de calcul des assemblages à brides circulaires avec joint - Partie 5: Méthode de calcul pour assemblages avec joints pleine face

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ICS:

23.040.60	Prirobnice, oglavki in spojni elementi	Flanges, couplings and joints

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Foreword

This document (CEN/TR 1591-5:2012) has been prepared by Technical Committee CEN/TC 74 “Flanges and their joints”, the secretariat of which is held by DIN.

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EN 1591 "*Flanges and their joints — Design rules for gasketed circular flange connections*" consists of the following parts:

— *Part 1: Calculation method;*

— *Part 2: Gasket parameters;*

— *Part 3: Calculation method for metal to metal contact type flanged joint* (CEN/TS);

— *Part 4: Qualification of personnel competency in the assembly of bolted joints fitted to equipment subject to the Pressure Equipment Directive;*

— *Part 5: Calculation method for full face gasketed joints* (CEN/TR).

1 Scope

This Technical Report gives guidance for the calculation of full face gasketed joints on the basis of the calculation method given in EN 1591-1.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 1591-1:2001+A1:2009, *Flanges and their joints — Design rules for gasketed circular flange connections — Part 1: Calculation method*

3 Symbols and abbreviated terms

A_{Ge} effective gasket area (= $\pi * d_{Ge} * b_{Ge}$), [mm^2], see Equation (26)

b_{Ge} effective gasket width, (mm), see Figure 2

b_{Gi} interim value of effective gasket width, [mm]

b_{Gseal} effective sealing gasket width, [mm], Figure 9

b_{GQ} compressed gasket width, [mm], Figure 2

d_{F1} gasket force acting diameter for zone A, Equations (12), (14)

d_{F2} gasket force acting diameter for zone B, Equations (7), (10)

d_{F3} resultant gasket force acting diameter on outside area of the real gasket, [mm], Equation (16)

d_{F4} resultant gasket force acting diameter on outside area of the equivalent gasket, [mm], Equation (19)

d_{G1} inside diameter of gasket theoretical contact area, [mm], Figure 1

d_{G2} outside diameter of gasket theoretical contact area, [mm], Figure 1

d_{G3} outside diameter of bolt holes part for the equivalent gasket, [mm], Figure 1

d_{G4} outside diameter of equivalent gasket, [mm], Figure 1

d_{Gi} interim value of effective gasket diameter, [mm], Equation (25)

d_{Ge} effective gasket diameter, [mm], Figure 2

d_3 real bolt circle diameter, [mm], Figure 1

d_{3e} effective bolt circle diameter, [mm]

d_4 outside diameter of flange, [mm]

d_5 diameter of bolt hole, [mm], Figure 1

F_{Gmin} minimum gasket force, [N], Equations (28), (29), (30), (31)

F_{Greal} force on the real gasket, [N]

F_{Gequi} force on the equivalent gasket, [N]

F_{GzoneA} gasket force on the bolt holes zone A, [N], Equation (5), Figure 7

F_{GzoneB} gasket force on zone B, [N], Equations (5), (6), Figure 7

F_{GzoneC} gasket force on zone C, [N], Equations (5), (10), Figure 7

F_Q axial fluid pressure force, [N], Equations (29), (31)

F_R force resulting from external additional axial force and moment, [N], Equations (29), (31)

K_{seal} ratio of effective to sealing average gasket stress, Equation (27), (30), (31)

n_B number of bolts, Equation (11), (21), (23)

P internal pressure, [MPa]

$Q(x)$ gasket stress evolution versus gasket radius, [MPa], Equation (2)

Q_A minimum necessary compressive stress in gasket for assembly condition, [MPa], Equation (28), (30)

$Q_{AGe'}$ average stress on effective gasket area, [MPa], Equation (27)

$Q_{smin(L)I}$ mean effective required gasket compressive stress at load condition I, [MPa], Equations (29), (31)

$Q_{max,Y}$ yield stress characteristic of the gasket materials and construction, [MPa], Equation (22), (26)

Q_{seal} average stress on sealing gasket area, [MPa], Equation (27)

x radial position defined by $Q(x = 0) = 0$, [mm], Figures 4, 5, 6

x_{max} elastic behaviour gasket width, [mm], Figure 10

Subscripts

0 Initial bolt-up condition (assembly)

I Subsequent operating condition I

Superscripts

el elastic behaviour of the gasket is considered

pl plastic behaviour of the gasket is considered

4 Introduction

EN 1591-1:2001+A1:2009 and CEN/TS 1591-3 only deal with the Inside Bolt Circle (IBC) gaskets. For a Full Face (FF) gasket, the gasket reaction force application diameter is closer to the bolt circle diameter due to the gasket reaction on the outside part of the gasket.

The aim of this proposal is to give a method (based on EN 1591-1) enabling to include the full face gaskets within the scope of series EN 1591.

The method described in this document involves the following steps:

a) Geometrical definition of a homogeneous gasket (without any hole) equivalent in terms of reaction force to the real Full Face gasket with holes:

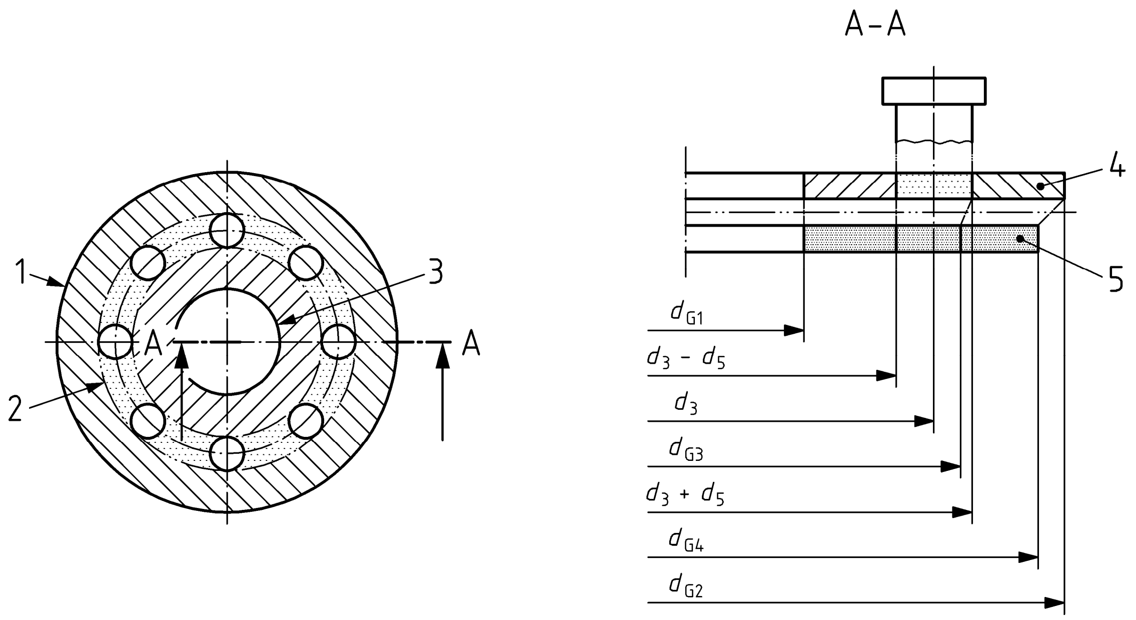
1) Partitioning of the gasket into 3 parts (internal part, bolt holes part and external part);

2) determination of the outside diameter of an homogeneous gasket part equivalent (for gasket force) to the bolt hole part, having the same inside diameter, considering full elastic behaviour of the gasket (d_{G3}^{el});

3) determination of the outside diameter of a homogeneous gasket part equivalent (for gasket force) to the external part, having an inside diameter of (d_{G3}^{el}) considering full elastic behaviour of the gasket (d_{G4}^{el});

4) determination of the outside diameter of a homogeneous gasket equivalent (for gasket force) to the real gasket, having the same inside diameter, considering full plastic behaviour of the gasket (d_{G4}^{pl});

5) determination of the outside diameter of the equivalent gasket (d_{G4}) as the maximum value of d_{G4}^{el} and (d_{G4}^{pl}) in order to maximize the gasket surface and the subsequent required bolt load.



Key

1 external area

2 bolt holes area

3 internal area

4 real gasket

5 equivalent gasket

Figure 1 — "FULL FACE" gasket areas division and definition of the equivalent gasket

b) Determination of the effective dimensions of the homogeneous equivalent gasket using the equations of EN 1591-1.

c) Modification of the tightness criteria verification, in order to take into account that only a part of the effective gasket width participates to the sealing (part inside the bolt hole circle).

5 Definition of an equivalent gasket

5.1 Gasket parts identification

The gasket can be divided into three parts as shown in Figure 1:

a) The Internal part (or sealing part) is the gasket part inside the bolt holes diameter. This part of the gasket is the part already treated in EN 1591-1 and is the part associated to the sealing behaviour of the bolted flange connection;

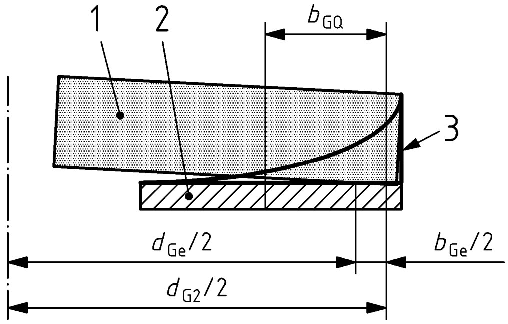
b) The Bolt holes part is the part of the gasket containing the holes enabling the bolt going through the gasket. The width of this part is equal to the bolt holes diameter;

c) The External part is the part outside the bolt holes diameter (d_5).

5.2 Gasket elastic deformation

5.2.1 General

For the compressed gasket width see Figure 2.



Key

1 flange

2 gasket

3 gasket stress distribution

Figure 2 — Compressed gasket width

5.2.2 Gasket modelling at unloading

The gasket elasticity modulus at unloading (E_G) depends on the initial gasket stress ($Q = F_{G0}/A_{Ge}$), see Figure 3. The test performed according to EN 13555 give tabulated values for E_G depending on the initial gasket stress F_{G0}/A_{Ge}. Thus the variation of E_G versus Q can be modelled by a linear relation for each interval [Q_n, Q_{n+1}].

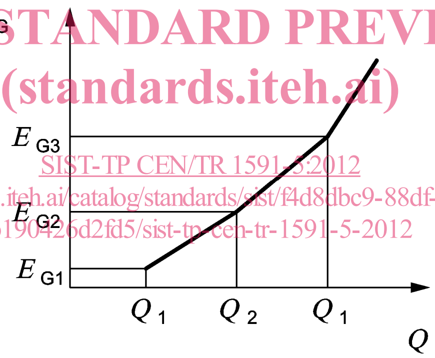


Figure 3 — Variation of E_G versus initial gasket stress Q

$$For\ Q_n \leq Q \leq Q_{n+1}$$

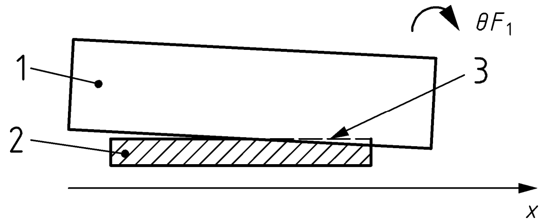
$$E_G(Q) = A_n \cdot Q + B_n = dQ / d\varepsilon$$
$$A_n = (E_{G,n+1} - E_{G,n}) / (Q_{n+1} - Q_n) \quad (1)$$
$$B_n = E_n - \left[(E_{G,n+1} - E_{G,n}) / (Q_{n+1} - Q_n) \right] \cdot Q_n$$

In the case of elastic deformation, considering the flange rotation (see Figure 4), leads to the following expression of Q versus radial distance x, using the same equations as in the CR 13642, with coefficients A_n and B_n for each initial gasket stress interval [Q_n, Q_{n+1}].

$For\ x_n \leq x \leq x_{n+1}$ with $x_0 = 0$

$$Q(x) = k \cdot (x - x_n) \cdot B_n \cdot \left[1 + \frac{1}{2} \cdot A_n \cdot k \cdot (x - x_n) \right] + \sum_{m=0}^{n-1} k \cdot (x_{m+1} - x_m) \cdot B_m \cdot \left[1 + \frac{1}{2} \cdot A_m \cdot k \cdot (x_{m+1} - x_m) \right] \quad (2)$$

NOTE This expression of Q replaces the expression $Q(x) \approx E_0 \cdot k \cdot x \cdot (1 + ½ \cdot K_1 \cdot k \cdot x)$ given in document CR 13642:1999, Equation (4.4). (The value of n = 0, leads to CR 13642:1999, Equation (4.4)). It should be noted that the expression of EN 1591-1:2001+A1:2009, Table 1 is based upon the hypothesis of a gasket elastic modulus for unloading depending linearly of the initial gasket stress $(E_G = E_0 + K_1 \cdot Q)$.

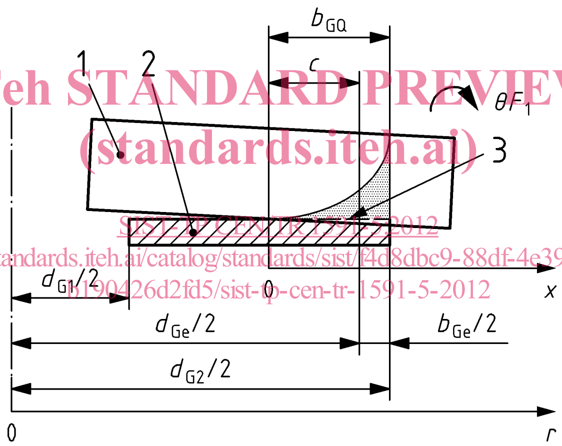


Key

1 flange
2 gasket
3 effective contact area due to flange rotation

Figure 4 — Flange rotation

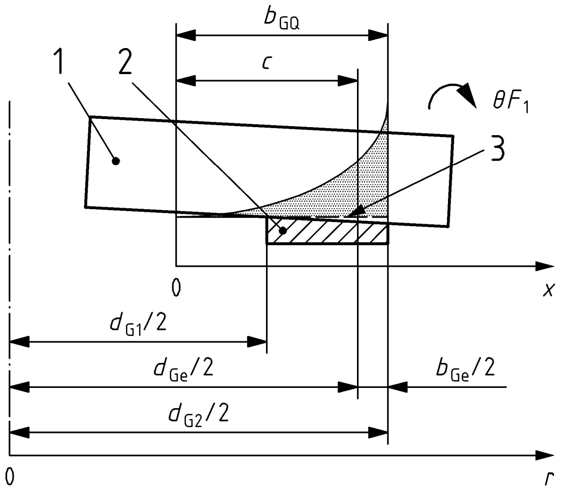
At this step there are two possible configurations, see Figure 5 and Figure 6:



Key

1 flange
2 gasket
3 gasket pressure contact profile on effective contact area

Figure 5 — Case with no contact on the inside part of the gasket



Key

1 bride (flange)

2 joint (gasket)

3 gasket pressure contact profile on effective contact area

Figure 6 — Case with contact on the inside part of the gasket

This leads to the following expressions:

$$r = d/2 = x + d_{G2}/2 - b_{GQ} \quad (3)$$

This last expression combined with the expression of $Q(x)$ (see Equation (2)) shown above leads to a polynomial of order 2 or 3 for the variable b_{GQ}.

Knowing d_{Ge} and F_G (which is the case in the determination of the effective gasket dimensions), this polynomial can be analytically solved, and the value of b_{GQ} found using Equation (4) below.

$$F_G = \pi \cdot d_{Ge} \cdot \int_{\max(d_{G1}/2 - d_{G2}/2 + b_{GQ};0)}^{b_{GQ}} Q(x)\,dx \quad (4)$$

5.2.3 Determination of the dimensions of the homogeneous part equivalent to the hole part (elastic case)

The gasket force on the hole part (zone A) is calculated by subtracting the force on the bolt holes surface (zone C) to the force on an homogeneous gasket part with dimensions equal to those of the bolt hole part (zone B), see Figure 7.

$$F_{G\,zoneA} = F_{G\,zoneB} - F_{G\,zoneC} \quad (5)$$

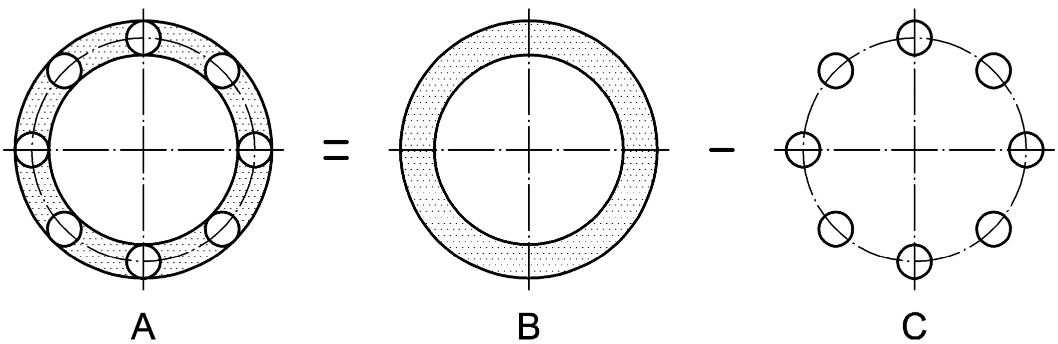


Figure 7 — Gasket force calculation on bolt hole part