International Journal of Pressure Vessels and Piping 138 (2016) 45–50

Contents lists available at ScienceDirect

International Journal of Pressure Vessels and Piping

journal homepage: www.elsevier.com/locate/ijpvp

# Sealing behavior of twin gasketed flange joints

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ARTICLE INFO

*Article history:*
Received 9 October 2013
Received in revised form
6 January 2016
Accepted 13 January 2016
Available online 15 January 2016

*Keywords:*
Gasketed flange joint
Twin gasket
Contact stress
Bolt preload
Residual stress

ABSTRACT

Sealing performance of gasketed flange joints depends mainly on the behavior of gasket. In the present work, a three dimensional finite element analysis has been carried on a gasketed joint with single and twin gaskets having nonlinear material properties, to find the influence of gasket contact stress and sealing performance of the joint. Bolt preload required for safe operation of twin gasketed joints has been formulated by modifying the ASME code. A comparison is made on sealing performance of gasketed joint with single and twin gaskets. The contact pressure of twin gasketed joint is examined by varying the design parameters such as individual gasket widths and space between the gaskets. Contact pressure in single and twin gasketed flange joints at different operating conditions, viz., bolt preload and internal pressure have been investigated. It is observed that the flange joint with twin gasket can withstand higher internal pressure.



## 1. Introduction

Gasketed flange joints are common in pressure vessels and piping systems. Performance of gasket depends on the contact stresses developed during assembly and operating conditions. Gaskets are relatively soft compared to other members in the joint. Hence, the stiffness of gasketed joint is approximately equal to the stiffness of gasket [1]. One of the major problems in gasketed flange joint is leakage of fluid through the pores between gasket and flange face. Main reason for this leakage is reduction of contact stress between gasket and flange face over a period of time because of the relaxation of bolts and permanent deformation in gasket. Design calculations for strength of flange joint with ring gasket was developed by Taylor-Forge [2]. They have considered the effect of taper hub in calculation. Simple rules have been developed to define the contact behavior near outside diameter of flanges due to flange rotation in flange joint. Gasket factors, 'm' and 'y' play an important role in calculating the bolt preload for leak proof operation of gasketed flange joint. These factors are based on experience and experimental inference.

Robertson [3] presented an experimental procedure for determination of elastic stress distribution in rings and flanges in bolted flange joints. Tests were performed on plain rings of different thicknesses loaded uniformly around the inner edge to study the behavior of flange ring. Influence of bolt loading on flange thickness, number of bolt holes and length of hub was studied by performing a series of tests on model flanges. Zahavi [4] carried out nonlinear finite element analysis of flange connections considering the changes in geometry and friction. This allowed greater accuracy in predicting the leakage and computing bolt forces. Bouzid and Derenne [5] presented an analytical method to predict the distribution of gasket contact stress by taking into account the nonlinear behavior of gasket material. They showed that leakage can occur for flange rotation even below 0.3° and suggested that the nonlinear unloading behavior should be included for better estimation of gasket stress distribution at low contact stresses.

Murali Krishna et al. [6] investigated the effect of gasket contact stress on sealing performance in bolted flange joints. Nonlinear properties of gasket at room temperature were obtained experimentally. The influence of different gasket materials and number of bolts on flange rotation and gasket contact stress were presented. Also, the effect of internal pressure on bolt load was discussed.

In the present work, sealing behavior of twin gaskets in flange joint is studied. An empirical relation to determine the bolt preload for minimum compressive stress required on gaskets to keep the twin gasketed joint leak-tight is proposed. A finite element model for determining the contact stress distribution in twin gasket has been developed. Analysis has been carried out considering the loading and unloading characteristics, nonlinearity and hysteresis

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http://dx.doi.org/10.1016/j.ijpvp.2016.01.001
0308-0161/

**Nomenclature**

| | |
|---|---|
| $b$ | Effective gasket seating width |
| $b_1$ | Effective inner gasket seating width |
| $b_2$ | Effective outer gasket seating width |
| $b_a$ | Average seating width of inner and outer gasket |
| $b_g$ | Effective space between gaskets |
| $G$ | Diameter at location of gasket load reaction |
| $G_1$ | Diameter at location of inner gasket load reaction |
| $G_2$ | Diameter at location of outer gasket load reaction |
| $G_g$ | Diameter at location of space between the gaskets |
| $k$ | Geometric factor |
| $m$ | Gasket factor |
| $P$ | Internal pressure |
| $w$ | Basic width of gasket or space taken for analysis |
| $w_1$ | Inner gasket width |
| $w_2$ | Outer gasket width |
| $w_g$ | Space between inner and outer gasket |
| $W_{sg}$ | Total bolt preload in single gasketed flange joint |
| $W_{tg}$ | Total bolt preload in twin gasketed flange joint |
| $y$ | Gasket factor |

of the gasket material. Effect of different bolt preload and internal pressure on gasket contact stress and flange rotation are studied with asbestos filled spiral wound gaskets under various loading conditions in Section 6.1. Mechanical behavior of twin gasketed joint is examined by varying the parameters such as individual gasket widths and space between gaskets in Sections 6.2 and 6.3. A comparison has been made on the performance of gasketed flange joint with single and twin gaskets.

## 2. Bolt preload

Design calculation for bolted flange joints are made for operating and gasket seating condition. Generally, the operating conditions remain to be severe due to the effect of internal fluid pressure. The bolt load ($W_{sg}$) required during operating condition to resist the effect of hydrostatic end force along with internal pressure (P) and the minimum gasket compressive stress required to keep the gasketed joint leak-tight are provided in ASME code [7].

$$W_{sg} = 0.785G^2P + 2\pi bmGP \tag{1}$$

$$Residual\ stress\ line = mP \tag{2}$$

Eqs. (1) and (2) give the minimum bolt preload and gasket compressive stress required to prevent the leakage from single gasketed joint. The minimum gasket compressive stress required to prevent leakage from the gasketed joint is called residual stress which depends on the gasket material and internal pressure. These equations are provided in ASME code for single gasketed joint.

In twin gaskets, two gaskets are placed adjacent to each other radially. The entities to be included in twin gasketed flange joint formulation are inner gasket, outer gasket and space between them. The total bolt preload for twin gasketed flange joint ($W_{tg}$) is formulated by extending the equation available for single gasketed flange joint. The second term in Eq. (1) corresponding to contact load on single gasket is extended for twin gaskets. The contact load in twin gasketed flange joint is given by Eq. (3) including effect of inner and outer gasket along with effective space ($b_g$) between them.

$$Contact\ Load = 2\pi b_1 mG_1P + 2\pi b_2 mG_2P - 2\pi b_g mG_gP - 2\pi b_g G_g kP \tag{3}$$

$$W_{tg} = Fluid\ load + Contact\ load \tag{4}$$

$$W_{tg} = 0.785G_g^2P + 2\pi b_1 mG_1P + 2\pi b_2 mG_2P - 2\pi b_g mG_gP - 2\pi b_g G_g kP \tag{5}$$

$$k = \frac{b_g}{b_a} \tag{6}$$

Eq. (5) has been developed for twin gasketed flange joint to calculate the required bolt load to prevent leakage for a given internal operating pressure. When the space between gaskets is zero ($b_g = 0$), Eq. (5) reduces to Eq. (1) and the twin gaskets without space act as a single gasket. Further, the residual stress line (minimum gasket compressive stress) for twin gasket is derived from that of single gasket.

$$Residual\ stress\ line = (m - k)P \tag{7}$$

Eq. (7) gives the residual gasket stress line for twin gasketed flange joints. In Eq. (7), the term ($b_g/b_a$) accounts for the influence of space between gaskets on required residual compressive stress. From Eq. (7) it can be seen that a decrease in space between gaskets and increase in width of inner gasket increases the residual stress.

## 3. Joint configuration

### 3.1. Geometry

The gasketed flange joint consists of flange, bolting and gasket. The weld neck (WN) flange (80 mm NPS, Class 600 in ASME/ANSI B 16.5) which is commonly used in high pressure vessels and piping along with M20 bolts whose dimensions are shown in Fig. 1 is considered in the finite element analysis.

### 3.2. Material properties

In the present study, an asbestos filled spiral wound with nonlinear mechanical behavior during loading and unloading is used. Gasket properties are specified by pressure-closure plot shown in Fig. 2. The flange and bolt material considered are forged carbon steel and chromium steel respectively with material properties shown in Table 1.

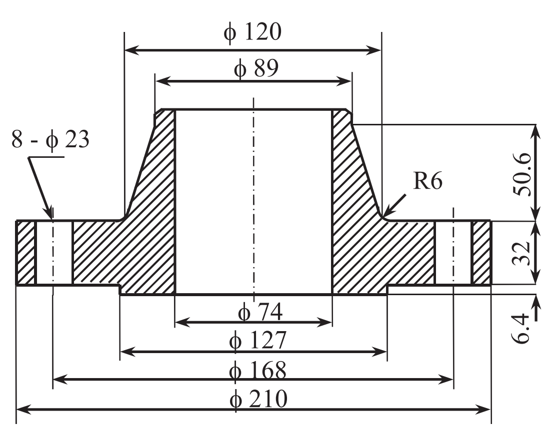


**Fig. 1.** Dimensions (in mm) of the pipe flange.