

Behaviour of Non-Metallic Gaskets in Small and Medium Pressure Conditions

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The paper presents experimental research results on the behavior of non-metallic gaskets in small and medium-pressure conditions. Gaskets have been tested in real conditions, i.e. taking into account both the width and thickness of the gasket and flange thickness influence. It should be specified that, with regard to asbestos use prohibition in the EU countries, experimental investigations were carried out on gaskets made of marsit without asbestos.

Keywords: pressure vessels, flanged joints, asbestos-free materials, tightness

Despite its apparent simplicity, a flanged joint raises difficult problems of design, because it is constituted of very different elements: bolts, nuts, flange, and gasket. They, in turn, may have different constructive forms, being possibly constructed of materials with different properties (in terms of tensile stress, flexibility, relaxation, creep, mechanical and thermal fatigue etc.). In addition, it must be taken into account the behavior of the welded joint between flange and body of the vessel, and the influence of temperature difference between the constructive elements of the assembly [1-3]. So as to ensure the tightness of such construction, the simultaneous action of all the parameters specified should be taken into account. This is a problem whose solution is very difficult and laborious. A study by the Pressure Vessel Research Council (PVRC) in the USA [4] showed that the defects of flanged joints are due to the following cases: improper installation (26%), deterioration of flanges (25%); damage of gasket (22%); bolts are not tightened (15%); misalignment of flanges (12%).

The function of a flanged assembly is to create and maintain tightness under conditions which vary greatly from case to case, depending on the nature and type of requests. To meet these different conditions of work, the choice of flanged joints should take into account many factors, including [5]:

- working conditions: working fluid pressure, working fluid temperature, chemical reactivity of the working fluids, corrosive characteristics of the working fluids, viscosity, concentration;

- flange: configuration (type), sealing surface finishing, material, corrosion resistance, erosion, request of flange, rigidity, mounting tolerances;

- gasket: tensile stress, resistance to creep, relaxation of tension, elasticity, expected lifetime, comparative cost, chemical compatibility, fire resistance, easy installation, combined resistance to temperature and pressure.

These types of constructions have been known for a long time. So, it is expected to be already well known and, consequently, when choosing the right solution this should cause no problem. However, experience has shown that there are still difficulties in this domain [6, 7]. The difficulties clearly deepened once with new problems arisen from the replacement of asbestos-containing seal

materials, and the needs to reduce leakage and improve the economic aspects.

As regards gaskets used to ensure tightness flanged joints, it should be noted that the most used construction material was asbestos. The widespread use of this material to ensure tightness was justified by its relatively low price, the trouble-free processing and good resistance to very different working conditions.

With all its remarkable qualities, asbestos use was banned because of its impact on human health, namely damage to human respiratory system. In addition, asbestos has been classified by the American Institute for Cancer Research in the first group of materials "for its clear carcinogenic effect on human health".

Consequently, EU states have adopted a series of laws restricting the sale and use of this material, including Directives 83/478 EEC, 85/610 EEC, 87/217 EEC and 91/659 EEC. Also, to verify the use of asbestos in workplaces, Directives 83/477 EEC and 91/82 were issued [8, 9].

Meanwhile, the industry has developed a new generation of non-asbestos sealing materials. Thus, in the recipe of sheets used to manufacture gaskets, asbestos fibers were replaced by fibers of other materials: aramid (amide fiber), carbon fiber, cellulose, glass, etc. Generally, these materials may have a performance equal or even better to that of asbestos fibers, but they require a careful choice and special manufacturing technologies.

On the other hand, limited experience on using this new type of material requires undertaking intense theoretical and experimental research to determine the sealing capacity in different conditions. Given the absence of data in this area, the gaskets used in this work were made of marsit without asbestos (Marsit FA-A2), achieved at S.C. Fermit S.A., Râmnicu Sărat.

Experimental determinations

Considering the large number of factors that can influence the behaviour in service of a flanged joint, experimental research presented in this article was limited to determining the influence of geometrical parameters the flange and the gasket have on the inner pressure at which fluid leakage may occur from a vessel under pressure.

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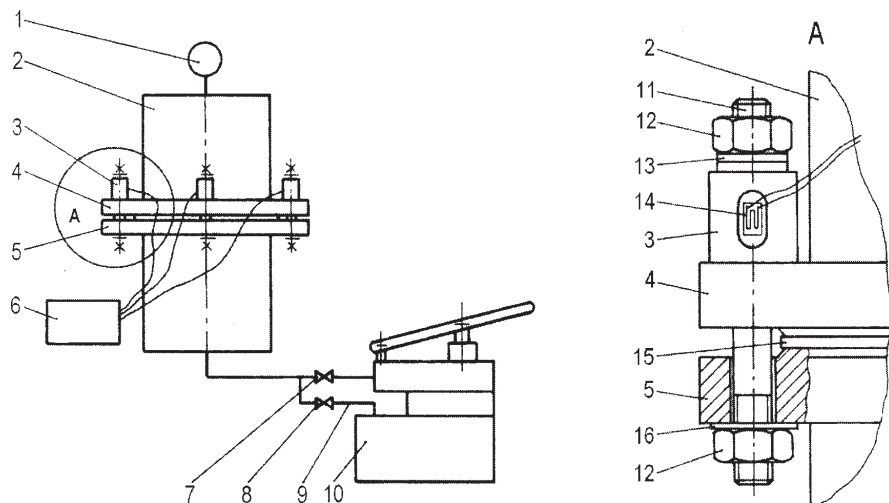


Fig. 1. Experimental set - up:
1- manometer; 2- vessel; 3- bushing;
4, 5- flanges; 6- electronic stress meter
device; 7, 8- taps; 9- by - pass pipeline;
10- pump; 11- bolt; 12- nut; 13- axial
bearing; 14- electrical resistive transducer;
15- gasket; 16- washer

Thus, the experimental set-up shown in figure 1 allows the determination of the internal pressure that can cause a loss of tightness due to the flanged joints, depending on the pressure on the gasket surface, width of the gasket and thickness of the flange.

To be able to determine the influence of parameters specified on the tightness of the flanged joint, two cylindrical vessels were used, with an inner diameter of 0.250 m and a wall thickness of 6 mm. Vessels are provided with flanges of different thicknesses ($T_{F1} = 20$ mm and $T_{F2} = 10$ mm), each with six M16 bolts.

Gasket with thickness $T_G = 1.5$ mm and widths $W_1 = 5$ mm, $W_2 = 10$ mm and $W_3 = 20$ mm were tested. The inner diameter of gaskets used was $D_i = 0.259$ m.

Before starting the experimental determinations, one of the conditions was to ensure a uniform tightening of the bolts. In the case of experimental set-up presented in figure 1, this condition is met by using resistive strain gauges transducer 14, located on bolts 11. Axial bearing 13, mounted between nut 12 and bushing 3, is to eliminate friction between the nut and the bushing.

The values for the specific deformations of bolts are adjusted by the help of electronic stress-meter device 6, by gradually tightening nut 12, in correspondence with the value of the pressure on the gasket surface.

Thus, if we intend to achieve a pressure on the gasket q , the total force at mounting is:

$$F = q \cdot A_G, \quad (1)$$

and the axial force loaded on one bolt is determined with relation:

$$F_1 = \frac{F}{n}, \quad (2)$$

where

n is the number of bolts;

A_G – the actual contact area between the flange and the gasket.

Further, knowing the force F_1 , the specific deformation of bolts, corresponding to a certain pressure on gasket q , can be determined using Hooke's relationship:

$$\varepsilon = \frac{F_1 \cdot L}{E \cdot A_p}, \quad (3)$$

where:

E is the modulus of elasticity the bolts construction material has, $E = 2.05 \cdot 10^5$ N/mm²;

A_p - minimal transverse area of the bolts;
 d - diameter of bolts on the thread bottom;
 L - length of bolts.

To determine the value of internal pressure p_i , which causes loss of tightness, it is first adjusted, by the electronic stress-meter device 6, the pressure on the gasket: $q = 2$ MPa. Meanwhile, water (20°C) is introduced in vessel 2 by pump 10.

The value of water pressure in the vessel is gradually increased until the first drops of liquid appear between the gasket and the flange. This value of internal pressure p_i is registered in the table with experimental results.

Afterwards, pressure on the gasket 2 is increased to 2 MPa and, for each step, it is registered the inner pressure that leads to a tightness loss.

Results and discussion

By the help of experimental data achieved, diagrams were drawn for the variation of internal pressure p_i , whereat the tightness loss is produced due to the flanged joint. For diagrams drawing, the next parameters were taken into account: the pressure on gasket q , gasket width W , and the thickness of flange T_F . Gasket thickness was the same in all experimental determinations: $T_G = 1.5$ mm.

It should be noted that the research in this domain is usually carried out on devices that simulate the behaviour of flanged joints, by compressing a gasket between two rigid surfaces. This time, the experimental results have been obtained under real conditions, i.e. using vessels with different thickness flanges.

Thus, in figure 2, experimental data is shown for the gaskets with thickness $T_G = 1.5$ mm, which were tested for a vessel with the flanges thickness $T_{F1} = 20$ mm. Examining the results of this figure, one may note that, at the same value of pressure on the gasket, the flanges with bigger widths of the gaskets ensure tightness at high inner pressures. For example, if the value of the inner pressure is 4 MPa, when gaskets with width $W_2 = 10$ mm are used, tightness is ensured by a set of 7.3 MPa pressure on the gasket. However, when used gaskets with $W_1 = 5$ mm width, at the same value of inner pressure of 4 MPa, the tightness is ensured only at a 12.3 MPa pressure on the gasket.

The same influence of the gasket width can be noticed as well in the case of the gaskets with thickness $T_G = 1.5$ mm, tested for a vessel with the flanges thickness $T_{F2} = 10$ mm (fig. 3).

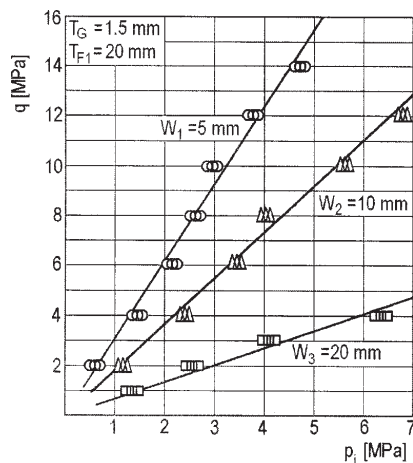


Fig. 2. Dependence of gasket specific pressure vs. inner pressure whereat tightness loss appears, for the 20 mm thickness flanges

Moreover, comparing the results shown in figures 2 and 3, it is noted that, at the same value of the gasket width and the same value of the internal pressure, greater thickness flanges have better behavior. Thus, as can be seen, they can ensure the tightness for a lower clamping of the gasket. For example, at a value of 4 MPa internal pressures, the assembly of the flanges with 20 mm thickness (10 mm the width of the gasket and 1.5 mm the thickness of the gasket), the pressure on the gasket to ensure tightness is 7.3 MPa.

At the same time, in the case of a flanged joint with a 10 mm flanges thickness, for the same sizes of the gasket and to the same value of the inner pressure, tightness is ensured by a set of 8.7 MPa pressure on gasket. That requires a 19% higher pressure.

It should be noted that, in accordance with Normative C4-2003, in the case of gaskets made of marsit with a thickness of 1.5 mm, the minimum value of the pressure that can be put on the gasket is $q = 25.5$ MPa. So, as can be ascertained, it accounts for about a three times higher value, than the ones derived from experimental research. This could lead to gasket destruction in the mounting phase.

Curves of tightness loss shown in figures 2 and 3 can be used directly to determine the pressure on gasket q , depending on the inner pressure of the working fluid.

Conclusions

Given the trend to reduce the use of asbestos fibers, a new generation of asbestos-free materials has been developed in the sealing industry. This required undertaking some intense theoretical and experimental research to determine the physical and mechanical characteristics of these materials, in different working conditions.

In this context, the aim of the present work was to establish the influence the geometrical parameters of the gaskets made of asbestos-free materials have on the tightness of flanged joints. It was also taken into account the influence of flange widths on the working fluid pressure that caused the tightness loss appear.

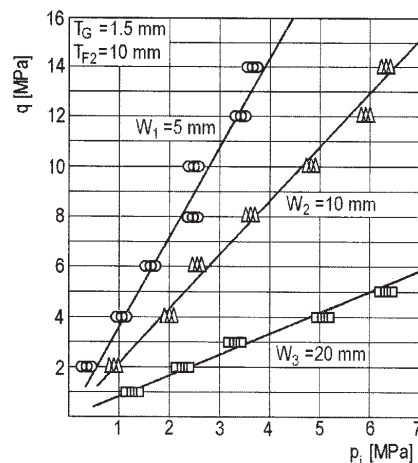


Fig. 3. Dependence of gasket specific pressure vs. inner pressure whereat tightness loss appears, for the 10 mm thickness flanges

The experimental researches have produced the following results:

- for the same value of the specific pressure per gasket, the higher width gaskets lose their tightness to higher values of the inner pressure;
- builds with thicker flanges, of high rigidity, has been proven to ensure a better tightness;
- on the basis of tightness loss curves $q = f(p_i)$, computing relations can be suggested for the minimal specific pressure necessary to mounting, in the case of the gaskets with a different thickness, and for flanges with different rigidities.

It should be noted that experimental results were achieved in real conditions, i.e. using vessels with flanges of different thicknesses.

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