Gaskets: The Weakest Link

Careful design and selection will avoid leaking flanges and costly shutdowns

By Trinath Sahoo, Indian Oil Corporation Ltd.

Click here for full pdf version of this article - includes all graphs, charts, tables and author information

Gaskets are the weakest link in the piping system of a process plant. Therefore, it is important not to ignore the design and selection of the gaskets to prevent flange-leakage problems and avoid costly shutdowns.

A gasket performs the basic function of keeping the process fluid where it belongs. It acts as a retaining seal between rigid stationary surfaces. The gasket will stay seated when the friction, relative to the sealing surface, is large enough to overcome the pressure exerted on it from the process fluid. Because gasket material is normally softer than the parts it is sealing, the gasket will, to some extent, flow into the irregularities in the joint faces to close off any leakage pathways.

In general, there are two main types of gaskets: those used in full-faced joints and those wholly situated within the bolt circle (the circle defined by connecting the centers of the bolts). Full-faced gaskets have more surface area, so a greater compressive load will be required for sealing compared to that used by those used within the bolt circle. In general, full-faced gaskets are used in piping systems operating pressures up to about 300 psi, whereas gaskets situated within the bolt circle can be used for pressures as high as 3,000 psi.

Stress acting on a gasket

When a flanged joint is pressurized, the flange is subjected to two opposing stresses, as shown in Figure 1. The bolt load (or assembly load) produces a compressive stress on the flange. The hydrostatic-end force is the product of the working pressure times the aperture area of the gasket. The difference in these two forces produces a resultant force acting on the gasket, which is known as the residual-gasket load:

Residual-gasket load = Bolt load – Hydrostatic-end force **(1)**

In addition to the residual load, the gasket experiences a side force, called the blowout pressure, which is due to the internal fluid pressure that tends to extrude the gasket through the flange-clearance space. The net stress acting on the gasket (per unit area) at operating condition is known as the residual-gasket stress, and is determined by the product of the internal pressure and the gasket factor, m:

Residual-gasket stress =

m.(internal pressure) **(2)**

In order for the flange to seal, the residual-gasket stress must be greater than the fluid pressure.

Design codes for piping systems traditionally classify gasket materials by two factors, Y and m, which are properties related to the gasket material. The Y factor is the initial gasket stress, or the minimum design seating stress. This quantity is the load acting on the gasket before the system is pressurized. The m factor is defined as the ratio of the residual gasket stress to fluid pressure, which means, from Equations (1) and (2):

m = (bolt load – hydraulic end force)/[(gasket area).(internal pressure)] **(3)**

Most of the pressure-vessel codes have design values for Y and m.

Material selection

The total bolt force (Fb) that is required to generate the proper gasket-seating stress is determined by the relation:

$$F_b = N_b . S_b . A_b \quad \textbf{(4)}$$

where Nb is the number of bolts, Sb is the bolt stress and Ab is the stress area of the bolt. The value of the total bolt force must be sufficiently high to seat the gasket in to the flange. In most cases, the flange geometry is fixed by design and the inner and outer diameters of the gasket are known. The actual compressive stress available to seat the gasket (Sg) is then

$$S_g = F_b / A_g \quad \textbf{(5)}$$

where Ag is the area of the gasket. The gasket material must be selected so that it will seat satisfactorily under this stress; the gasket material must have a minimum seating stress equal to, or less than, the available stress calculated in Equation (5). The minimum seating stress is normally supplied by the manufacturer of the gasket, and is also available in different design codes.

As a rule of thumb, the product of the operating temperature and pressure can be used as a general indicator for which type of gasket material to use. Table 1 gives the maximum operating temperature, and the product of operating temperature and pressure, for the most common gasket materials (discussed below); a given material can be considered if the product P.T is below the value provided in Table 1.

Common gasket configurations

Aside from the choice of gasket material, the configuration or structure of the gasket is also significant. Following are descriptions of four major types.

Graphite foil: The physical and chemical properties of graphite foil make it suitable as a sealing material for relatively arduous operating condition. In an oxidizing environment, graphite foil can be used in the temperature range of –200 to +500°C, and in a reducing atmosphere, it can be used at temperatures between –200 and 2,000°C. Because graphite foil has no binder materials, it has excellent chemical resistance, and is not affected by most of the commonly used chemicals. It also has very good stress-relaxation properties.

Spiral-wound: As the name implies, the spiral-wound gasket is made by winding a preformed-metal strip and a filler on the periphery of a metal winding mandrel. All spiral-wound gaskets are furnished with a centering ring. In addition to controlling compression, these rings serve to locate the gasket centrally within the bolt circle. Inner rings are used where the material (such as a gasket with PTFE filler) has a tendency for inward buckling. The ring also prevents the buildup of solids between the inside diameter of the gasket and the bore of pipe. Under vacuum condition, the ring protects against damage that would occur if a pieces of a broken component were drawn into the

the system. Spiral-wound gaskets can operate at temperatures from –250 to 1,000°C, and pressures from vacuum to 350 bar. Spiral-wound gaskets up to 1-in. diameter and up to class number 600 require a uniform bolt stress of 25,000 psi to compress the gasket. Larger sizes and classes require 30,000 psi to compress the gasket.

Ring-joint: Ring-joint gaskets are commonly used in grooved flanges for high-pressure-piping systems and vessels. Their applicable pressure range is from 1,000 to 15,000 psi. These gaskets are designed to give very high gasket pressure with moderate bolt load. These joints are not generally pressure-actuated. The hardness must be less than that of the flange material so that proper flow of material occurs without damaging flange surfaces. The most widely used ring-joint gaskets are of the oval and octagonal type.

Oval-type gaskets contact the flange face at the curved surface and provide a highly reliable seal. However, the curved shape makes it more difficult to achieve accurate dimensioning and surface finishing. Oval gaskets also have the disadvantage that they can only be used once, so they may not be the best choice for sealing flanges that have to be opened routinely.

On the other hand, because they are constructed of only straight faces, octagonal-type gaskets are usually less expensive, they can be dimensioned more accurately, and are easier to surface finish than the oval-type gasket. However, a greater torque load is required to flow the gasket material into imperfections that may reside on the flange faces. Octagonal gaskets can be used more than once.

Corrugated-metal: This type of gasket is available in a wide range of metals, including brass, copper, copper-nickel alloys, steel, monel, and aluminium. Corrugated metal gaskets can be manufactured to just about any shape and size required. The thickness of the metal is normally 0.25 or 0.3 mm, with corrugations having a pitch of 1.6, 3.2, and 6.4 mm. The sealing mechanism is based on point contact between the peaks of the corrugations and the mating flanges.

Factors affecting performance

In addition to the material and the configuration, there are several other factors that need to be considered when selecting the correct gasket for a given application; the most important ones are briefly described below.

Surface finish: The surface finish of a gasket — which consists of grooves or channels pressed or machined onto the outer surface — governs the thickness and compressibility required by the gasket material to form a physical barrier in the clearance gap between the flanges. A finish that is too fine or shallow is undesirable, especially on hard gasket materials, because the smooth surface may lack the required grip, which will allow extrusion to occur. On the other hand, a finish that is too deep will yield a gasket that requires a higher bolt load, which may make it difficult to form a tight seal, especially when large flange surfaces are involved. Fine machining marks applied to the flange face, tangent to the direction of applied fluid pressure can also be helpful. Flange faces with non-slip grooves that are approximately 0.125 mm deep are recommended for gaskets more than 0.5 mm thick; and for thinner gaskets, grooves 0.065 mm deep are recommended. Under no circumstances should the flange-sealing surface be machined with tool marks extending radially across the gasket-sealing surface; such marks could allow leakage.

Gasket thickness: For a given material, it is a general rule that a thinner gasket is able to handle a higher compressive stresses than thicker one. However, thinner materials require a higher surface finish quality. As a rule of thumb, the gasket should be at least four times thicker than the maximum surface roughness of the flange faces. The gasket must be thick enough to occupy the shape of the flange faces and still compress under the bolt load. In situations where vibration is unavoidable, a thicker gasket than the minimum required should be employed.

Bolt loading: Bolt loads also affect the choice of materials thickness. Basically, the gasket material must be thick enough to deform sufficiently to accommodate any irregularities or inequalities in the flange faces under the available bolt load. The lower this load, the greater will be the required thickness, and vice versa. However, the thickness will also depend on the material's compressibility. In general, it is desirable to use multiple bolts that are equally loaded to give a uniform stress over the gasket area. Using many small-diameter bolts is preferable to using few large-diameter bolts.

Gasket width: In order to reduce the bolt load required to produce a particular gasket pressure, it is advisable not to have the gasket wider than is necessary. For a given gasket stress, a raised face flange with a narrow gasket will require less pre-load, and thus less flange strength than a full-face gasket. In general, high-pressure gaskets tend to be narrow.

Stress relaxation: This factor is a measure of the material's resiliency over a period of time, and is normally expressed as a percentage loss per unit of time. All gasket material will lose some resiliency over time, due to the flow or thinning of the material caused by the applied pressure. After some initial relaxation, the residual stress should remain constant for the gasket.

Gasket external diameter: For two gaskets made of the same material and having the same width, the one with a larger outer diameter will withstand a higher pressure. Therefore, it is advisable to use a gasket with an external diameter that is as large as possible.

Temperature: An increase in temperature will degrade the strength of the gasket material, causing it to deform. This will change the bolt load and thus modify the residual stress. A poor gasket material that suffers high deformation with increasing temperature will show high relaxation and collapse or extrude at high temperatures under moderate internal pressure.

Fluid properties: The gasket material must be resistant to corrosive attack from the fluid. It should chemically resist the system fluid to prevent serious impairment of its physical properties.

Troubleshooting

There a number of situations where a gasket can be damaged. Some of the most common problems and suggested remedies are presented here.

Gasket is excessively extruded: When the seating stress is too high, the gasket will be squeezed or extruded through the space between the flange faces. When this occurs, one should select a gasket material that has better cold-flow properties, or a material with a better load capacity.

Gasket is excessively crushed: Another problem that arises when the stress is too high is crushing of the gasket. A gasket material with a better capacity to handle the load and seating stress should be considered. If the gasket material cannot be changed, the crushing can be reduced by selecting a thinner gasket, or one with a larger area. Other remedies are to consider reducing the number of bolts used, or, if possible, a redesign of the flange.

No apparent gasket compression achieved: When the stress is insufficient to achieve adequate compression of the gasket, the obvious remedy is to increase the torque applied to the bolts. A better compression is achieved if the bolts are tightened in sequence, that is, one after the other rather than crosswise. Keep in mind that the gasket may relax as the temperature increases, so the bolts should be retightened after the system reaches the operating temperature. When a seal is still not achieved, a gasket material with a lower seating stress or high-tensile-strength bolt should be considered. Alternatively, one can use a thicker gasket, or reduce the area of the gasket to allow for a higher seating load. Don't overlook potential problems associated with the bolts themselves. Make sure that the bolt threads are long enough to allow nuts to make contact with metal faces. If possible, increase the number or diameter of the bolts used for the flange.

Gasket is badly corroded: This is an obvious sign that the gasket material is not compatible with the process fluid, and a replacement material with improved corrosion resistance is required.

Gasket is mechanically damaged: When the gasket is not properly placed in the flange, it will be damaged by either the overhang of the raised-flange face or the flange bore. To prevent this from happening, one should make sure that the gasket is properly centered in the joint during installation. One should also review the sizing of the gasket to make sure it was not sized too large.

Gasket is substantially thinner on the outer diameter than the inner diameter: This problem can arises when the flange is bent or if the flange has rotated. One possible remedy is to alter the gasket dimensions so that the gasket-reaction force is closer to the bolts, which will minimize bending. A softer gasket material, or a smaller gasket area can be considered to lower the required seating stress.

Gasket unevenly compressed around the circumference: This is an indication that the bolts were not tightened correctly. Again, when installing the gasket, keep in mind that the best compression is achieved when the bolts are tightened in sequence.

Refer to file: GasketsPJN June05.pdf