FLUID SEALING ASSOCIATION FSA

From the voice of the fluid sealing industry

SEALING SENSE

How do I determine bolt torque for flanged connections?

Controlling the load is essential to ensuring the gasketed joint will seal properly. Previous *Sealing Sense* articles have examined the types of gaskets to use, how flange finish affects gasket sealing and major pitfalls to avoid to properly assemble a gasketed joint. However, regardless of the type of gasket, controlling the load is probably the most important criteria for getting a gasketed joint to seal. A big problem is the load on the gasket cannot be measured directly and easily during installation.

However, applied torque on the flange bolts can be measured and controlled and is one of the most frequently used methods to control gasket load. This article explores bolt torque and the major considerations for converting measurable bolt torque into the gasket load necessary to seal a flanged connection.

Bolt Torque

Torque is the turning force measured in foot-pounds (ft-lb) or inch-pounds (in-lb) applied to tighten (turn) the nut on a bolt. Torque can be measured during flange assembly with a properly calibrated torque wrench. In a bolted flange, the applied torque generates the axial load in the bolt. The bolt acts like a spring. Tightening the nut stretches the bolt, which increases the load on the gasket. The relationship between torque, the turning force, axial bolt force and gasket load can be expressed by the simplified formula:

$$T = (k \cdot f \cdot d)/12$$

Where:

T = Torque in ft-lb
k = Dimensionless nut factor
f = axial force in pounds
d = Nominal bolt diameter in inches

The nut factor is a “modified” friction factor, but a nut factor involves more than just friction. It is more of a multiplier “in total,” taking into account many other load losses. If the same torque is applied, a 0.1 nut factor would produce twice the axial force as a 0.2 nut factor. Small changes in the nut factor can result in large changes in the load experienced by the gasket. This illustrates the need for a well-lubricated bolt, nut and washer.

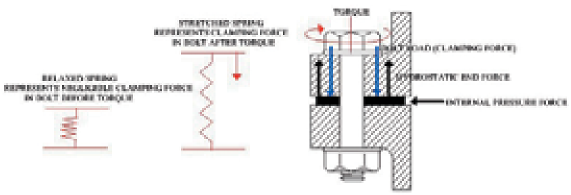

Figure 1. Forces on a bolted connection

Forces on a Bolted Connection

As described above, the bolts act like springs pulling the flanges together. They need to be stretched enough to keep the load on the gasket as the system is pressurized and as pressure and temperature cycle during normal usage. Additional loading above the minimum load required to seal will give the bolted joint flexibility to absorb these load changes and a safety margin to maintain the seal as these system forces fluctuate.

Bolt yield strength is a measure of the load required to stretch the bolt to its maximum length or stretch and still allow it to spring back to its original length. If the bolt is overstretched and is loaded beyond its yield strength, the bolt will not “spring back” when the load is removed. Overloading bolts can cause them to stretch beyond their yield strength and actually result in lower loads exerted on the gasket, after additional external and application loads are applied to the joint.Continued tightening of the bolts will not necessarily increase gasket load or stop a gasketed joint leak, and may lead to bolt failure.

The bolt may also lose its compressive load if it is not stretched enough and the system relaxes beyond the amount the bolt has been stretched. It is often recommended that a bolt be loaded to approximately 50 to 60 percent of its yield strength to ensure the "spring" is stretched enough. However, this recommendation should be tempered by the amount of gasket stress and flange stresses generated; check to ensure that the applied load will not overload and damage the gasket or the flange.

Bolts come in a variety of grades, each with individual yield strength and properties. Proper bolt selection is critical to the proper assembly of a bolted flange joint.

Gasket Design Requirements

We have a torque wrench to measure the torque during assembly and a formula to calculate the torque based on the gasket load, but what is the gasket load needed to generate a seal? The *f*, or force, portion from our torque equation is composed of two major parts, as noted by the design rules for raised face pipe flanges in the Boiler and Pressure Vessel Code. First is the force needed to compress and hold the gasket in place. The load generated by the bolts has to compress the gasket so it conforms to the flange surfaces, and to "seat" the gasket into the flange. This involves the gasket unit seating load or factor, *y*.

Second is the combined force needed to:

1. Overcome the hydrostatic end forces generated by the internal fluid pressure trying to push the flanges apart
2. Compress the gasket enough to hold it in place when the internal pressure is trying to penetrate through the gasket and/or gasket/flange sealing surfaces
3. Maintain some residual load on the gasket after the hydrostatic load has unloaded the gasket, which involves the gasket factor *m*.

The forces needed to compress the gasket for an effective seal vary with the type and style of gasket, the degree of flange tightness, system fluid, as well as temperature and pressure. The ASME *m* and *y* gasket factors determine the loads needed on the gasket, but it is best to get a recommendation from the gasket manufacturer. Note: the *m* and *y* gasket factors often listed are non-mandatory, "minimum" values, and do not necessarily speak to the leak tightness of a given joint.

The Code Design equation utilized to determine a minimum seating load on the gasket is as follows:

$$Wm2 = (\pi \bullet b \bullet G)y$$

Fluid Sealing Association

Sealing Sense is produced by the **Fluid Sealing Association** as part of our commitment to industry consensus technical education for pump users, contractors, distributors, OEMs and reps. *This month's Sealing Sense was prepared by FSA Members Mark Pollock, Brian Hasha, Pasche Raty and Jim Lingenfelder.* As a source of technical information on sealing systems and devices, and in cooperation with the **European Sealing Association**, the FSA also supports development of harmonized standards in all areas of fluid sealing technology. The education is provided in the public interest to enable a balanced assessment of the most effective solutions to pump technology issues on rational total Life Cycle Cost (LCC) principles.

The **Gasket Division** of the FSA is one of five with a specific product technology focus. As part of their mission, they develop publications such as the *Metallic Gasketing Technical Handbook* as well as joint FSA/ESA publications such as *Guidelines for Safe Seal Usage—Flanges and Gaskets* and *Gasket Installation Procedures*. These are primers intended to complement the more detailed manufacturer's documents produced by the member companies.

The following members of the **Gasket Division** sponsor this *Sealing Sense* series:

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The first combination of parameters is basically an effective gasket area based upon pi times a derived gasket width *b*, which is different for different compression configurations and gasket types, and *G*, which is a gasket load reaction diameter. The derivation of these values for all of the different gasket types and flange compression configurations is beyond the scope of this article, but can be found in product literature and in the Boiler and Pressure Vessel Code.

Note that some manufacturers utilize a gasket area much closer to the actual area of gasket sealing surface under compression as opposed to the *effective* area illustrated above, giving a much more conservative number. This will still comply with the Code, since the Code gives *minimum* loads. This area is then multiplied by the gasket factor *y*, to obtain the load Wm2. The greater the *y* value, the larger the load required to "seat" the gasket.

The second load consideration is a combination of two factors, the hydrostatic end load on the flanged joint and a residual gasket load. This load is determined by the following equation:

$$Wm1 = ((\pi \bullet G^2 \bullet P)/4) + (2 \bullet b \bullet \pi \bullet G \bullet m \bullet P)$$

The first portion of this equation represents a term to derive the hydrostatic end forces. These are calculated by multiplying the pressure *P* by the effective internal area of the gasket ($\pi \cdot G^2/4$) where *G* is the load diameter, which is typically around the midpoint of the compressed gasket area. The second term in the above equation is the required residual gasket load. It is calculated by multiplying the pressure *P* by an effective gasket area ($2 \bullet b \cdot \pi \bullet G$) and then multiplying this load by the gasket factor *m*. In essence, a gasket with a higher *m* factor will require a higher residual load.

The code anticipates higher installation bolt loads than these design values as a safety factor against leakage under operating conditions and to allow for joint relaxation in operation. It anticipates the possible need for initial bolt loads that may be much greater than the minimum design value, provided that excessive flange distortion and maximum gasket load capacities are taken into consideration.

Consequently, nearly all flanges use considerably higher load values for *installation*. Installation loads are often more than twice the minimum design loads. We recommend contacting gasket manufacturers for their recommended installation gasket loads.

Summary

The greater of the two values—*Wm1* or *Wm2*—will dictate the minimum required design bolt load. The minimum required bolt load divided by the number of bolts in the flange will determine the minimum *f*, or force, needed to use the torque equation.

After calculating the torque, ensure the bolts are not over-stretching and exceeding their yield strength, or some predetermined design stress. Additionally, check to see if the bolts are stretched enough for them to compensate for creep, pressure and temperature cycling and other load losses.

A detailed look at the torque and loading required to seal bolted flange joints can be found in John Bickford's book *Gaskets and Gasketed Joints*.

Next Month: *What are the benefits and pitfalls of expanded PTFE/graphite packing?*

We invite your questions on sealing issues and will provide best-effort answers based on FSA publications. Please direct your questions to: sealingquestions@fluidsealing.com.

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