European Sealing Association e.V.

Determination of bolt torque for flanged connections

Following on from the article introducing bolted joint technology, this month we look in more detail at how to determine bolt loads for flanged joints.

By Rainer Zeuss, ESA member

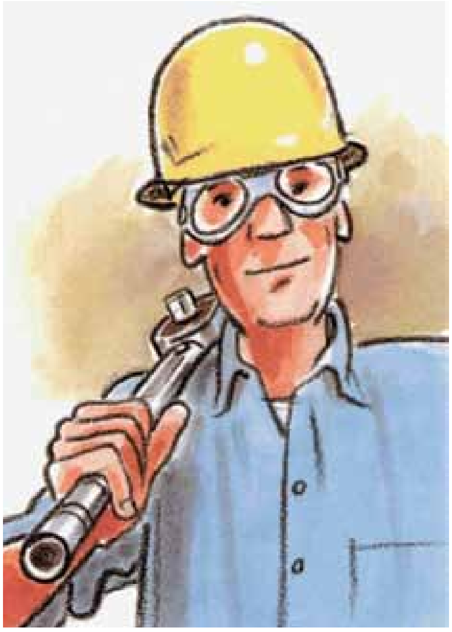
Controlling the load is probably the most important criteria, together with suitable gasket selection for the application, to ensure a gasketed joint will seal properly. The big problem is that the load on the gasket cannot be measured directly and easily during installation.

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 how bolt torque should be calculated and applied to seal a flanged connection.

Bolt torque

Torque is the turning force measured in Newton metre (Nm) applied to tighten (turn) the nut on a bolt. 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 axial load in the bolt is very much influenced by friction between bolt, nut and washer. Small changes in friction can result in large changes in the load experienced by the gasket requiring a well-lubricated bolt, nut and washer assembly.

Another major impact on the axial load in the bolt is the method of assembly. Torque should be applied with a properly



calibrated torque wrench, but more precise methods are available to improve the result, see Table 1 (note, similar information exists in other standards such as annex C of EN1591-1).

Method of assembly	Variation in bolt load [%]
Controlling yield strength	± 9 % to ± 17 %
Controlling angle of rotation	± 9 % to ± 17 %
Hydraulic tensioning	± 9 % to ± 23 %
Torque wrench	± 17 % to ± 43 %
Impact wrench or spanner	± 43 % to ± 60 %

Table 1: Variation of bolt load according VDI 2230 "Systematic calculation of high duty bolted joints"

Forces on a bolted connection

The bolts act like springs pulling the flanges together. They need to be stretched sufficiently to maintain 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 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 allow it to return 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 result in lower loads being 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 joint leaking, but may lead to bolt failure. The bolt loses its compressive load if not stretched sufficiently and the system relaxes beyond the amount the bolt has been stretched. Recommended bolt loads should be in the region of 40% to 100% of yield strength to ensure the "spring" effect is generated. However it is important to ensure that the applied load does not compromise the integrity of the gasket and/or the flange, so consultation with your gasket supplier is recommended. It is important to consider gasket surface stress. For small diameter and fibre based sealing materials maximum surface stresses should not be exceeded.

Bolts come in various materials and grades with individual yield strengths and properties. Proper bolt selection is critical to the proper assembly of a bolted flange joint.

Gasket design requirements

The gasket load or bolt force needed is composed of two major parts. First is the force needed to compress and hold the gasket in place. The load generated by the bolts has to compress the gasket to conform to the flange surfaces and "seat" it into the flange.

Second is the force needed to:
1. Overcome the hydrostatic end forces generated by the internal pressure trying to push the flanges apart,
2. Compress the gasket to hold it in-situ when the internal pressure is trying to penetrate through the gasket matrix and/or gasket/flange sealing surfaces,
3. Maintain a residual load on the gasket after the hydrostatic load has unloaded the gasket.

The degree of leak tightness of a given joint may vary according to the compression forces, type, style and gasket material, degree of flange tightness, system media, as well as temperature and pressure.

Bolt torque determination for flanged connections

Many gasket manufacturers in Europe provide computer programs to calculate bolt torques and/or make values in table form available. These programs and tables provide a useful estimate, but as only bolt force and compressed gasket area are used in relation to each other there are other aspects which need to be considered:
1. The mechanical limits of the flanges,
2. The tightness or leakage class,
3. External moments and forces ,
4. Variation in bolt load which is dependent on the method of assembly,
5. Relaxation or creep of gaskets which can reduce gasket seating stress dramatically.

Presently the standard which does consider all the above is EN 1591-1. Various computer programs according to EN 1591-1 are available on the market today. These can be used for the proper calculation of flange connections, either by end users or by engineering companies. Gasket manufacturers offer the relevant gasket factors needed for calculation. In addition the Münster University of Applied Sciences provide data on many manufacturers gaskets through their database available at www.gasketdata.org As a rough rule of thumb double the gasket pressure cuts leakage to a tenth.

Therefore the gasket pressure should always be chosen at its maximum feasible limit, without exceeding the maximum mechanical strength of bolts, flanges and gasket. This not only reduces leakage but also provides additional safety and therefore higher plant availability.

Conclusion

We recommend contacting gasket manufacturers for their advice. The calculation according to EN 1591-1 is a standard which provides a proper stability proof and a leak tightness proof at the same time. To obtain the optimum flange connection working at its best, the correct assembly procedure is important. EN1591-4 "Qualification of personnel competency in the assembly of bolted joints fitted to equipment subject to the Pressure Equipment Directive" addresses this important area and will be featured in a future article.

The European Sealing Association (ESA) has produced this article as a guide towards Best Available Techniques for sealing systems and devices. These articles are published on a regular basis, as part of their commitment to users, contractors and OEM's, to help to find the best solutions for sealing challenges and to achieve maximum, safe performance during the lifetime of the seal. The ESA is the voice of the sealing industry in Europe, collaborating closely with the Fluid Sealing Association (FSA) of the USA. We are pleased to acknowledge the help of our colleagues in the FSA for the background document, which was published originally as a Sealing Sense article in Pumps and Systems magazine. For more information, please visit www.europeansealing.com.