Common assembly methods for bolted flange joints: an overview

Improper assembly of bolted flange joints is a major source of leakages. Therefore, regulations and guidelines for tightening have been developed. There are various methods available to tighten bolts. Each method has its plusses and minuses, but the key factor is the control of the tightening and the target gasket load. This improves bolted flange connection reliability, reducing the probability of unwanted leaks.

As stated in VDI 2200, flange joints consist of three different elements (flanges, bolts, and seals), which are to be considered as a cooperating group. An improper design or assembly of this system can cause leakages and, as consequence, undesired environmental issues. For this reason, the technical committee of the CEN member states has developed a complete set of regulations, which goes from the design of bolted flange connection (EN 1591-1, 2 and 3) to the qualification of personnel for assembly (EN 1591-4). Several industries have adopted these recommendations and collected them in guidelines, like the German Chemical Industry Association (VCI) did, also proving how important bolted flanged joint assembly is in process plants. Following the above-mentioned approach, fugitive emissions from bolted joints can be kept below the designed levels, but how practically can such a result be obtained?

Avoid uncontrolled manual tightening

The key factor to obtain a leak-free connection, or better, a connection that reaches the designed tightening class, is to maintain the gasket in a proper state of stress. Such a condition is not only difficult to obtain, since there are several parameters in flange joints that influence the gasket stress, but also because gasket assembly stress cannot be easily directly measured during installation.

So, how can I control gasket stress? The answer is theoretically easy, using a proper and controlled tightening method to load the flange bolts. This means that uncontrolled manual tightening should be avoided because this method allows no control of gasket load. Thus, easily resulting in an over or under stressing of the gasket, as the tightening procedure is left to an operator's experience and feeling.

How to properly control tightening in a bolted flange connection? Several methods can be adopted according to which variables we are going to supervise. When we tighten a bolt, we apply a torque to the nut, which results in a nut turning and the bolt stretching, thus creating the required preload. Consequently, we can decide to control tightening via torque, turn, force/pressure or stretch, or even a combination of them. Depending on the assembly method used, there are variations in the resulting bolt load; here below you can find a table that summarizes these variations.

In the following section, we'll give a quick overview of the most common assembly methods used.

Torque wrench tightening

Tightening flange bolts with torque wrenches is probably the most common procedure for joints assembling. Torque wrenches are instruments used to apply a determinate value of torque to a fastener. Several types of torque wrenches are available on the market: beams, clickers, and electronic ones. Torque wrenches are relatively delicate tools that can degrade over time. They require careful use and should be calibrated regularly. With this method, each bolt is tightened individually following a crosswise sequence, with

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Table 1: Variation of bolt load according VDI 2230

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 %

exception of the last pass which is a clockwise sequence, in four incremental target stress points (typically at 30%, 50%, 100%, and another pass at 100% of target torque as indicated by calculations). The described procedure has some limitations which can be summarized as different bending behavior for each bolt, higher gasket stress variation in respect of stretch control methods and higher bolt preload scatter due to elastic interaction. For these reasons, when in a demanding application, more precise methods of assembly should be used.

Hydraulic wrench tightening

Hydraulic wrench tightening is again a torque-controlled tightening method but, instead of operating it manually, hydraulically actuated tools are used. The use of such instruments increases the tightening speed and for this reason, they are preferred in industrial applications, due to time-saving. Hydraulic wrenches are also favored in those heavy-duty applications where extreme torques are required.

Pneumatic torque wrench tightening

Pneumatic torque wrenches are relatively small and lightweight tools designed to produce high torque outputs. There are several types of pneumatic torque wrenches on the market according to the different torque ranges required but they have not to be confused with an impact wrench. The torque output of a pneumatic torque wrench is given by controlling air pressure supply while with an impact wrench it is impossible to measure the resulting torque.

Hydraulic tensioner tightening

Hydraulic tensioner tightening is a load control method that allows loading several bolts at the same time to generate the required preload. This preload depends on load losses which are caused by several factors during tensioning such as thread deflection and embedding of the nut on the flange assembly. Tensioners are tools that are made of different components, which vary according to the different models available. These can be summarized as a bridge, a body with a piston, and a thread insert. The thread insert, which is the threaded section of the tensioner, is screwed to the bolt free end, above the nut position. Once the complete set of tensioners has been positioned on the bolts, the pressure is applied to the system, resulting in an extension of the piston that stretches the bolt. During this phase, the system has a controlled amount of load which is then retained by running correspondent nuts. After this step, tensioners are depressurized and removed, and the tightening is completed.

Elimination of torsion

This assembly method offers several advantages over tightening techniques, which has been described above, but it is far away from perfection. A great advantage of this procedure is that the bolt undergoes only axial load, thus eliminating torsion. In torque tightening, particularly at high loads and/or friction factors, torsional/axial stresses may increase at the point that causes the bolt to yield before its actual theoretical value is achieved. Elimination of torsional stress means that the bolt can be stretched with a higher load without exceeding the yield strength limit. A drawback of this tightening method is that tensioners require longer bolts because the thread length of the stud bolt should be extended with at least the equivalent of the stud diameter, protruding above the nut.

Conclusions

Several factors influence the performance of bolted flange connections, but one of the most important ones is the assembly method because only with a proper tightening, the bolt preload to reach the designed tightening class can be achieved. It is well-known that the major part of leakages is caused by improper assembly. For this reason, regulations and guidelines for tightening have been developed all over the world. In this article, we have given a quick overview of some of the most common tightening methods adopted in industrial plants, neglecting other procedures, such as yield controlled tightening and angle-controlled tightening, and other important parameters during assembly, such as lubrication and use of washers.

Each described method has its advantages and drawbacks, but the key factor is that every procedure allows to control tightening and the target gasket load. This improves bolted flange connection reliability, reducing the probability of unwanted leaks.