Common assembly methods for bolted flange joints: an overview

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

<table>
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<th>Method of assembly</th>
<th>Variation in bolt load [%]</th>
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<td>Controlling yield strength</td>
<td>± 9 %, 10 ± 17 %</td>
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<tr>
<td>Controlling angle of rotation</td>
<td>± 9 %, 10 ± 17 %</td>
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<tr>
<td>Hydraulic tensioning</td>
<td>± 9 %, 10 ± 23 %</td>
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<tr>
<td>Torque wrench</td>
<td>± 17 %, 10 ± 43 %</td>
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<tr>
<td>Impact wrench or spanner</td>
<td>± 43 %, 10 ± 60 %</td>
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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.

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exception of the last pass which is a clock-
wise 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 meth-
ods 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, hydrauli-
cally actuated tools are used. The use of
such instruments increases the tighten-
ing 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 wrench-
es 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 summa-
rized 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 fric-
tion 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 tight-
ening 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 tighten-
ing, 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 tight-
ening 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 lubri-
cation and use of washers.

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