Slug wrenches - yes or no?

Simple, efficient and cheap or simply not good enough?

Slug wrenches are common tools for joint assembly in high density pipe industries, such as the oil and gas, processing and construction industry. Instructions on how to use them for tightening purposes, are found in technical descriptions, installation instructions etc.

Slug wrenches are cheap, easy to carry and only require muscle force to work, but do they really ensure that the tightening is done correctly? And in the end, are they really that cheap?

Introduction

Tightening a bolt can be an easy or a very complicated task – depending on what you want to achieve. However, the minimum requirement of any joint is that the clamp load must be higher than the external load acting on the joint, otherwise the joint will malfunction or break.

A commonly used tightening method for flange joints, especially in the oil and gas (O&G) and the construction industry, is working with slug wrenches. Slug wrenches are cheap, easy to use and they operate on muscle load. But the accuracy will not meet any standards or regulations. As a consequence, the risk of failure, malfunction and broken joints are imminent when using slug wrenches. Leaking joints have been reported as the main cause of hydrocarbon release in the UK offshore industry.

Using a slug wrench is normally a two-hand or two-person operation; one hand or person swinging the hammer and the other one holding the wrench in place. The wrench holder is particularly exposed as it is possible to injure the hand with the hammer or getting stuck when the wrench moves.

The slug wrench always exposes the operator to a risk, while Injuries when using the torque or tensioning tools are – in most cases – a matter of not using them properly. It is also worth mentioning that the slug wrench can fall off the bolt and damage surrounding areas as it falls.

It's all about clamp load

$$F = \frac{T}{cD}$$

The relationship between clamp load and torque

The goal with the tightening is to achieve a clamp load higher than the external load acting on the joint. If the clamp load is less than the external load, the joint will separate which may lead to malfunction or failure. Examples of external loads can be static loads from the weight of a structure, hydrostatic forces in pressurized pipes etc.

The most common way of achieving the right clamp load is with torsional (torque) methods. The relationship between clamp load and torque is described in the equation show left. Where T is the applied torque [Nm], c is the friction coefficient and D is the nominal diameter of the bolt [m]. If the tightening is done on the same joint (C and D constant) but with different torque methods, the only factor influencing the clamp load is the torque. It is therefore important to use the right torque tools to achieve a consistent and correct torque.

The flange joint

Flange joints are normally made up of two flanges with a gasket in between. The principle of a bolted flange joint is to deliver enough clamp load to withstand the maximum service loads (Figure 1). In addition it is also very important that the clamp load is distributed evenly so the gasket seals the flange properly. Uneven distribution of the clamp load may cause leakage and damaged gaskets (Figure 2).

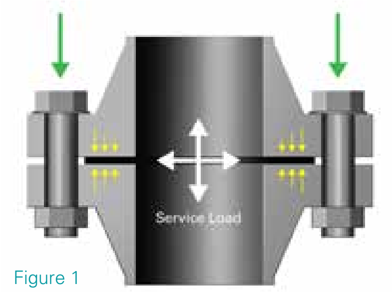

Figure 1

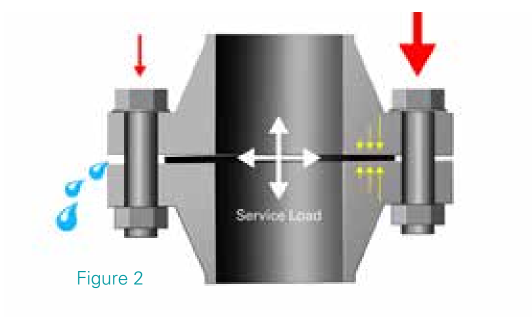

Figure 2

When a single torque tool is used the tightening should be made in stages following a cross-bolt tightening method (ASME PPC-1). Typically 3 stages at 30%, 60% and 100% of required torque are used together with a check pass at 100%, resulting in a total of 4 stages. Cross bolt torque tightening strategies for different flanges are shown in Figure 3.

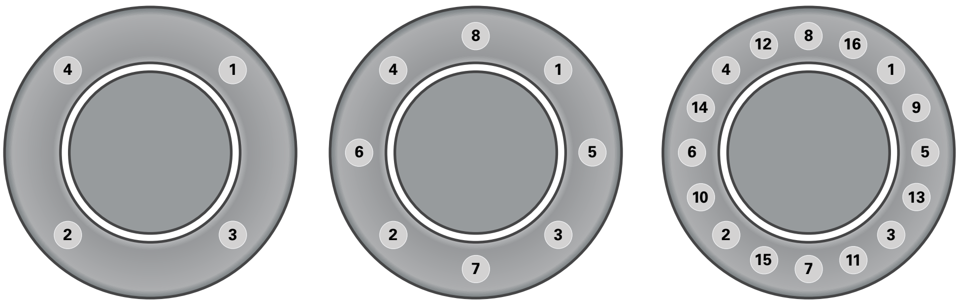

Figure 3 Cross-bolt tightening method according to ASME PPC-1

When 2 or 4 torque tools are used simultaneously it is possible to reduce the number of stages. A total of 3 stages are required for the two-tool setup (50-100-100%) and 2 stages are required with the four-tool setup (100-100%). Using multiple tools normally requires hydraulic tools connected to the same pump.

Methods similar to that of flanges are available for e.g. steel structure assemblies. The tightening according to EN1090-2 should be carried out in at least 2 stages, beginning at the most rigid part of the joint – to the least rigid part. The first stage is 75% of nominal minimum preloading and the second stage is 110%.

The accuracy of the slug wrench

The installed torque from a slug wrench depends solely on how hard the user strikes the wrench with the sledge hammer, or in other words, with what velocity the hammer hits the wrench. To control the tightening, the user has to strike the wrench with an exact velocity at the same spot on the wrench - every time. That is not easy, maybe even impossible, as seen in this example:

Given the data below and that the user can strike the exact same spot every time, how hard does the user have to hit the wrench to tighten the bolt to 400 Nm?

Sledge hammer weight: 2 kg

Wrench lever arm: 0.3 m

Answer: around 6.7 m/s.

It is highly unlikely that a user could be able to control the velocity of the hammer with that accuracy. He will probably end up at 5 m/s one time and 9 m/s another time which means that the torque ends up between 300 and 540 Nm (Table 1), an unacceptable spread when tightening a flange.

Completing a flange according to the 30-60-100-100 principle on an 8 bolt flange accurate enough with even distributed clamp load will be a real challenge with a slug wrench. Having different users working on the same flange will make it even more challenging!

Hammer velocity [m/s]	3	5	6.7	9	11
Installed torque [Nm]	180	300	400	540	660

The not so small leakage

In Norway leaks, fluids or gas, larger than 0.1 kg/s must be reported as they are a risk indicator for major accidents. In 2016 there were 11 such cases reported, an increase from previous years (Petroleum Safety Authority Norway). Leaks of that size are normally detected by leak detection systems, instrumentation, the crew etc.

A relatively small leakage of only a few drops or liters per minute are not likely to cause a major incident, but can be hard to detect. But as the drops adds up to a large volume over time the leak can become very expensive.

Below is a simplified calculation of a leakage in one flange joint. The fluid is light crude oil and one drop of oil is leaking out every 5 seconds (12 drops/min).

Size of leakage [mm]	2	3	4	5	6
Volume [liters/day]	0.40	0.59	0.79	0.98	1.19
Volume [liters/year]	145	214	290	360	435

This is the calculation for one flange joint. However, there are normally several hundred flanges and valves (maybe even thousands) on typical O&G sites. If a fraction of those are leaking, the total volume of leaked fluid or gas will be substantial.

Let us assume that one site has 600 flange joints and valves and that 25% of those are leaking. The total annual leakage for different sized orifices is seen in table below.

Leakage [liters/year]	21 760	32 167	43 520	53 927	65 280
Barrels*/year	137	202	274	339	411

1 bbl = 159 l

Not only is the loss in volume unacceptable but the time it takes to repair the leakage(s) is also considerable and may result in long downtimes. Another aspect of leaking chemicals is the hazard to the health of the crew and the negative impact on the environment.

How to do it without a slug wrench

Direct driven pneumatic, electric or hydraulic tightening tools are all better options than the slug wrench. Impact wrenches and pulse tools are usually not accurate enough but may be used for some 1st stage tightenings and for bolts smaller than 1".

The torque from direct driven pneumatic or hydraulic tools are set by a mechanical clutch or directly with the air pressure. In bolting the latter is the most common as it is easy to set different torques by adjusting the air or hydraulic pressure. This can be done anywhere making the tool suitable when applications vary or the tightening is made in stages. As long as the pressure is stable the tool will install the correct torque with approx. 5% accuracy.

Pneumatic clutch tools have to be preadjusted to make sure that they shut off at the correct torque level. The adjustment is normally done on a test joint so in the field adjustments are not easy to do. A clutch tool is therefore very convenient to use in an assembly environment where the same joints are tighten on a regular basis.

Electric direct driven tools are very accurate, versatile and easy to adjust. They measure the torque with a torque transducer and it is also possible to do torque and angle (torque and turn) tightenings in one shot. Electric tools require some kind of controller for setting up the tightening strategy. The controller can be integrated in the tool or it can be a part of the drive unit.

Standards, regulations and instructions

The O&G industry is not obliged to follow any specific regulations, but companies normally follow internal instructions on how to tighten joints.

There is however a European Directive (2010/75/EU) on industrial emissions (the Industrial Emissions Directive, IED) regulating pollutant emissions from industrial installations to e.g. air, water and land. The IED entered into force January 2013 and is minimum requirements for national legislation. The directive is focusing on all types of pollutant emissions, and leaking joints will affect the total emission.

The internal instructions used may be based on experience, non-regulatory standards such as ASME PPC-1 or a combination of both. ASME PPC-1 describes methods of tightening with respect to accuracy of the tool (hand tightening least good and bolt elongation best) but it also emphasizes the importance of assembly procedures, specific material properties, and operator training and competency.

The European Sealing Association (ESA) has a guide for safe usage of flanges and gaskets. Unless the flange has a metal stop the guide advises against using impact wrenches and spanners with long lever arm (called "scaffolding poles") as it is very important to apply the correct force evenly on the gasket.

The Eurocodes are European standards specifying how structural design should be conducted within the European Union. The codes are mandatory and have been in force since March 2010, replacing existing national building codes. EN1090-2 is the standard in the Eurocode system describing how to perform the tightening of joints. According to EN1090-2 the bolts shall

"…be tightened using a torque wrench offering a suitable operating range. Hand or power operated wrenches may be used. Impact wrenches may be used for the first step of tightening for each bolt.

The tightening torque shall be applied continuously and smoothly."

It also specifies the accuracy of the tool to ±4%. ±4% is impossible for a lug slug wrench and an impact wrench to deliver and it is hard to justify that a slug wrench applies the torque "continuously and smoothly".

Summary

Using a slug wrench might seem like a convenient method for high torque bolting applications – but it is not. The accuracy is not close to what standards, regulations or installation guides require and the risk of faulty joints and personal injuries are imminent when using slug wrenches for tightening. When including the costs for leakage, rework and unplanned shutdowns due to bad torquing, the cheap slug wrench becomes very expensive in the long run. Using direct driven pneumatic, electric or hydraulic nutrunners improves the quality of the joints, thus reducing the risk of joint failures and the cost related to that.

Sources

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