



Hydraulic torque wrenches

....it's all about the right prestress

In several branches of industry high demands are made with regard to (heavy) bolted joints. To achieve this a precision tool is required which provides the certainty of a good joint, but especially the correct bolt prestress. The appropriate tool for this purpose is a hydraulically driven torque wrench. In this article you will find further information about the principles behind hydraulic torque wrenches, the various application possibilities, and particularly the things you should pay special attention to when using these tools.

In spite of all kinds of new joining techniques, nuts and bolts still play an extremely important role in construction and mechanical engineering. Just think of offshore engineering, the chemical industry, or the construction of machines and pipelines. An important advantage of the bolted joint is the possibility to undo the joint for maintenance and repairs and to separate joined machine or construction parts.

■ High demands

Especially in heavy industry, bolted joints must comply with specific safety demands, which can be very stringent. There must be absolute certainty about the joint's operational strength. And although mounting (remounting), use, maintenance and conditions are described in manuals, it can never be completely certain that all this is complied with. Many designers therefore opt for safety by using more or heavier bolts than strictly necessary. It is, however, better to use a torque wrench to check the bolted joint, and to tighten it with the correct bolt prestress, in

accordance with designer requirements. And when working with torque values of 2000 Nm or more, the hydraulic torque wrench is the most universal tool.

■ The torque wrench

The torque wrench certainly isn't a new phenomenon. The first handwrenches can be found as far back as the beginning of the twentieth century, with a simple dial and pointer, operated by a spring mechanism. This will be sufficient for small nut and bolt applications where 'just about tight' is not good enough, and where safety requirements aren't very strict. However, for heavy joints where high demands are made, and where torques of approximately 2,000 Nm to 27,000 Nm are used, such as for pressure vessels in chemical industry, offshore piping and heavy constructions, the manual method cannot be applied. Precisely adjustable pneumatic or hydraulic torque wrenches should be used. The difference between pneumatic and hydraulic, purely constructionally, is a factor 1 to 100.

For the pneumatic method a pressure of 6 bar is used, while 700 to 800 bar is applied for the hydraulic torque wrench. Of course this is reflected in wrench construction. To achieve the same torque, a hydraulic torque wrench can be designed much lighter. Apart from that, air is compressible, which oil is hardly compressible. And although nowadays, even when working with a pneumatic wrench, torque can be monitored electronically, this is less precise than a hydraulic wrench. Otherwise, for light applications there are also precise handwrenches with a click-system or electronic monitoring.



Hydraulic square drive torque wrench in combination with a socket.



Using a hydraulic torque wrench, the bolted joint can be tightened in a controlled way, with the correct bolt prestress in conformity with designer requirements.

■ The hydraulic torque wrench

To tighten a nut with a hydraulic torque wrench, the linear movement of a hydraulic cylinder is converted to a rotary movement of a ratchet (25 to 30 degrees at a time), under high pressure (700 to 800 bar). The complete system consists of three components: the (electrically or air driven) hydraulic pump, the torque wrench with square drive and reaction arm, and one or more sockets or cassettes.

Hydraulic torque wrenches used to be made entirely in steel. However, the ratio between maximum torque and weight (including support arm) with these steel wrenches is very unfavorable. For a wrench with a maximum torque of about 4800 Nm, this is approximately 500 Nm per kilogram of weight. This means that a 4800 Nm maximum wrench weighs approximately 9 to 10 kg. Larger wrenches are even heavier and can't be handled by a single person.

These days a light, but extremely strong aluminum alloy with a very high tensile strength is used for the

housing. Only essential parts, like the ratchet drive, are made of steel. For such wrenches the ratio of maximum torque to weight is much more favorable, approximately 1200 Nm per kg of weight. The weight of such a wrench, including support arm, for a maximum of 4800 Nm is now only 4 kg. This is especially important when working from scaffolding, when working in high places and when transporting by helicopter.

The hydraulic cylinders in the torque wrench give double acting cylinders a higher operating speed and a more precise torque. Single acting cylinders must be put back into position by a spring, at the expense of pressure and time, let alone precision. Return speed depends on hose length, and with approximately 6 meters of length it is just about insufficient. Sockets are the simplest and cheapest tools to work with. These sockets are standardized, and there are two types: low and high. A disadvantage of high sockets is the greater tool height, so that it can't be supported over the complete height of the nut.

The exchangeable insert types are flatter and can be used for places which are difficult to get at. The reaction arm is used to transfer the reaction moment of the wrench to an adjacent nut or a machine or flange side.

■ Prestress and friction

One of the most important causes of bolted joint failure is incorrect prestress.

Although attention is paid to the torque value when tightening the nut, prestress is what it is all about. In spite of several well known measuring methods, prestress is still difficult to check. It's true that the designer knows the forces on machine parts or flanges, as well as the losses through friction and settling. The number of bolts, the bolt class and the required bolt prestress (kN) are included in the design. But later on, when these machine parts are repaired, chances are that during reassembly losses through friction and material settling are not accounted for.

Tips

What to watch when using a torque wrench

How do I support safely, the way the manufacturer prescribes in the manual?

For a modern wrench, made from light materials and with a maximum torque of 4800 Nm, for example, the reactive force on the support arm will be approximately 4 to 4.5 tons. For larger wrenches these reactive forces are much higher, and that's why these must be supported properly, to prevent distortion or damage of the work-piece and the tool, and to prevent accidents. Therefore a good and solid support is a first requirement for safe and proper use.

The best support is with the arm down, parallel to the socket. The torque produced by the reactive force and the torque of the wrench will approximately be equally high and counterbalance each other. Using the reaction arm at 90° horizontally and using the rectangular surface at the end of the reaction arm as support or contact point is not to be recommended at all, because a reactive force will be created on the arm and thus a bending force on the housing. The chances are that the wrench will distort and that the drive mechanism will be damaged.

However, when the bolts are very close together or placed against a wall, this could give problems with the support or even when placing the wrench on the nut. Should no proper support be possible, you should be able to overcome this using simple means, like filling the space between the reaction arm and the machine or the flange with a block of hardwood or steel. And although there is only little space, you will still be able to use the reaction arm the correct way, horizontally not below 90°.

Bearing on the washer, a bent surface or at the top of the nut is always wrong, because there will be every chance for the reaction arm to slip off. Sometimes you have to considerably lower the hydraulic pressure.

How to deal with 'frozen nuts'.

A rule of thumb when unscrewing nuts: at least once a torque of 1.5 times the tightening torque is required. Therefore you should invest in a wrench with 1.5 times the required capacity. This is slightly more expensive, but gives you the security of successful use. Nuts 'frozen' by corrosion and paint, however, sometimes need much more force to loosen. In this case the best solution is to use a wrench with at least twice as much torque. But it is better to use a high quality penetrating spray which eats away the corrosion within 15 minutes at the most. The break-away torque will be much lower, so that the disastrous ratchet effect in the wrench decreases, which also has an important influence on the tool's life span.

What is the influence of hose length and flow capacity?

The length of the supply and discharge hose is essentially unlimited, but a short length gives a higher operating speed. For the flow capacity of the hydraulic components the operating speed of the wrench at high capacity will also be higher.

How much prestress?

Basically you should give maximum (prescribed) prestress. However, it is important to pay attention to the strength of the bolt and the parts to be joined, the torque precision of the hydraulic tool, the safety factor of the total joint, the environment variables (temperature, corrosive fluids) and the external forces on the joint. Furthermore, for a correct prestress smaller bolts or fewer bolts are required, smaller flanges (piping), resulting in a construction which is less heavy and cheaper.

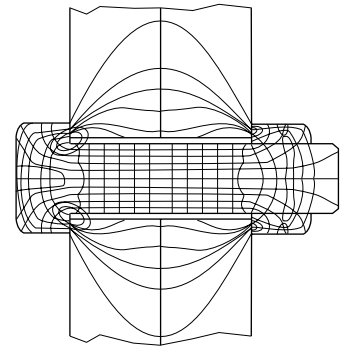
What problems are caused by incorrect prestress?

When prestress is too high, there is a risk of shearing bolts, stripping threads, and damaged machine parts or flanges. When prestress is too low, this results in loosening by vibration, bolt fatigue, creeping of the joint or fluid leakage (piping).

The torque value, or the force which is necessary to tighten a bolted joint, depends on a number of variables:

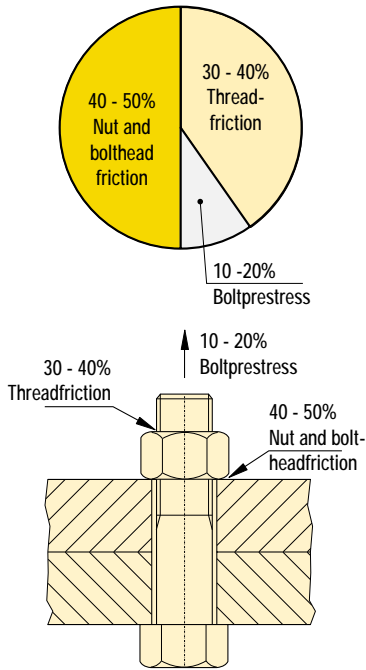
- Friction loss between nut and bolt
- Friction between nut surface and machine or flange part
- Thread geometry (quality)
- Tightening method and tool (torque wrench).

The largest friction is between nut and bolt threads, and between the nut and the part to be tightened. The friction losses can be considerable and depend on the friction coefficient between moving parts. With practically dry friction, a rough surface and material settling, loss can be so high, that there is hardly any prestress in the bolt. In many cases there will be no more than about 10% of the torque left for pure prestress. The rest is lost to friction and settling. The risk is, that the joint seems tight, but is in fact not tight at all.



A graphical reproduction of prestress occurring in bolted connection.

The following example is by way of illustration. During factory assembly, all machine parts are new and clean. However, after a number of years of use they are dirty, corroded, etc. When parts are disassembled and then assembled again, a lot of friction occurs. The wrench shows the correct torque value, but the required prestress will not be reached. When the parts are stressed again in use, the joint will be looser than required, increasing the risk of accidents.



Friction

The use of a washer is always recommended, because there will be a better spread of force. The friction coefficient can actually be decreased by means of lubricants. However, this calls for a warning, because friction could consequently be too low. The result is that prestress becomes too high, and could even be near the tensile limit. Should the joint then be pressurized (pressure vessels), this could result in expansion by a temperature rise (heat exchangers). In case of vibration (bridges), the risk of bolts shearing is certainly not hypothetical. Otherwise bolt stress can pass the yield point, so that the joint will loosen again after tightening.

■ Measuring prestress

From what precedes, it appears that a joint, depending on prestress and friction, might be too loose or too tight. That's why specific expertise is required to know which prestress is required, and when that prestress is reached. Measuring is the only way to achieve this. The 'simple' way is measuring bolt length change with a micrometer. At a certain calculated prestress, the bolt shows a given extension, depending on quality. Another method is measuring the rotation angle of the nut. When working with a torque wrench, for every bolt diameter at a given average friction, the torque (Nm) necessary to reach a certain change of length is known from experience. Using thread pitch and the rotation angle of the nut, the bolt extension can be calculated. To do this, the nut is tightened first, with a preliminary force of approximately 200 Nm, which is enough to press the machine or flange parts together without distorting the bolt. We call this the zero base. Subsequently the nut is turned to the required angle. Calculated marks (by computer) have been provided on bolt and nut. When the marks align, the correct value is reached. This way tightening is correct, independent of friction.

A very precise method of measuring prestress force is by

using an Ultrasonic and microprocessor combination. When tightening the nut, a tensile stress is created in the bolt, and consequently there is a certain extension. The propagation speed of the ultrasonic waves in a bolt decreases with increasing tensile stress and extension, and can therefore be used for measuring the prestress force in bolts. This method can provide very precise results, but is fairly expensive and must be carried out by specialists. A method which is used more often and also quite accurate, is to extend the bolt to the required prestress by means of a hydraulic cylinder (tensile stress). A manometer shows how much hydraulic pressure has been applied. Consequently the bolt stress can be calculated. The nut will be slightly loose and can be tightened quite simply. Then, while reducing hydraulic pressure, the accurate prestress is created. This method is more precise than the use of a torque wrench. The disadvantage, however, is that later on a loss of stress is created through bolt material settling. When a torque wrench is used, this is less likely to happen, because more time for settling is available during tightening. The fact is that the nut only turns about 25 degrees and is released for a little while every time, so that the bolt has a few seconds to 'breathe', and the molecules can settle.



The hexagon cassette hydraulic torque wrench. The slim nose radius and swivel couplers allow easy access in all positions.

Hydraulic bolttensioning, however, is a laborious and time-consuming method, requiring specialist knowledge. That's why this method is only used for applications where very high safety demands are made, like in nuclear reactors, pressure vessels, screw-type compressors, marine diesel engines and turbines.

■ Measuring during loosening

The designer usually gives the torque value for a certain friction coefficient. However, in cases where no data are known concerning the required prestress and the corresponding torque, sometimes the force (torque) necessary to unscrew the joint is measured. This solution, however, is less than ideal, because there is a risk that the nut is so tight, that perhaps 2.5 times the torque is needed. This can only be overcome by slightly loosening the nut, breaking it away from the corrosion first, and continuing to unscrew slowly while measuring the torque hydraulically from then on. In any case, this gives an indication of the prestress and the torque necessary for retightening. Nevertheless, the best way is to contact the manufacturer.

■ Which type of torque wrench?

The choice of torque wrench type depends on the application. Apart from capacity data, questions have to be answered like: 'is there enough height for using the wrench?' and 'is there enough space around the nut?' Generally, the rule of thumb is that the torque wrench must have a minimum of 30% more capacity than required. That leaves a capacity reserve which can be necessary for unscrewing bolted joints. For heavy applications, wrenches of twice the capacity are sometimes used. For random occurrences a heavier wrench can always be rented from a specialist. As far as available working space is concerned: when height is sufficient, a square drive will be most satisfactory. But if height is limited, it will be better to choose a low model with cassettes.

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The conventional method, time-consuming and brings operator fatigue.



An Enerpac hydraulic torque wrench brings safety and economy, along with reliable maintenance and reduces operator fatigue.

Enerpac offers optimum 'power-to-weight' range

Through application of light, high-tech materials and a one piece wrench housing, Enerpac hydraulic torque wrenches are extremely compact. The ratchet system has fine toothing, enabling high precision and preventing drive jamming. The double acting cylinders give precise torque at high operating speeds. The 800 bar operating pressure enables a high torque/weight ratio and offers more power reserve during operation. The revolving coupling can be turned 360 degrees at high pressure, so that the hoses can be positioned in any position. This is very important when working in tight spaces.

Thanks to the light, compact construction Enerpac wrenches are easy to handle and usable almost anywhere. Furthermore, the advantage of the hexagon cartridges and adapters is that these can be quickly replaced. No extra tools are necessary to do this.