AJAX FASTENERS Innovations
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WHICH METHOD OF TIGHTENING?

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Introduction

An integrity of a tensile bolted joint is totally dependent on how well the joint is tightened. There are several methods used in the industry to achieve correct tightness of a bolted joint. Depending on the importance of the joint it is extremely important to employ the correct method of tightening in order to achieve joint integrity. A well designed joint in not good enough if the correct tension cannot be achieved.

This paper summarizes the relative performance of available tightening methods.

Conventional methods of tightening

Although, most of the practitioners understand the importance of bolt tension in a bolted joint the conventional tightening methods only provide a vague indication of the bolt tension. Extensive research carried out on torque-tension relationships prove that under most uncontrolled situations using torque as a measure of tension can lead to a error as large as ±50%. Even under controlled conditions torque on its own is not a reliable measure of tension.

Hand Spanner:

Using a hand spanner is the most common method of tightening small to medium size bolts. Typically, people tighten the bolts using a hand spanner until they are satisfied that a sufficient tension is achieved. Usually this method may not be applied to critical joints. An error of ±35-50% is not uncommon in this type of tightening.

Pneumatic Impact Wrench/Rattle Gun-Uncontrolled:

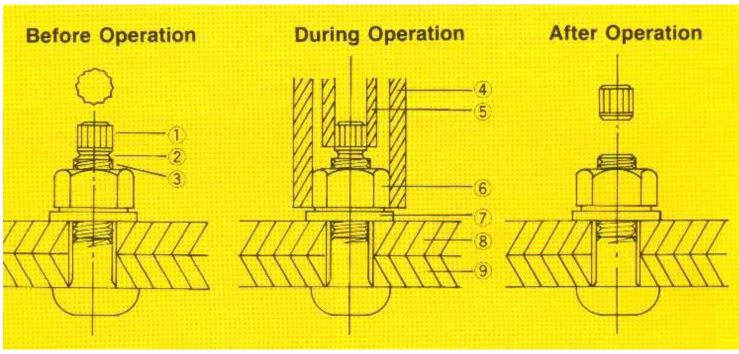
This method is applied for medium to large bolts. A pneumatic motor will drive the nut or the bolt with a of discrete impact torque. Due to dynamic effects of the impact wrench or rattle gun the instantaneous tension and torque may be much larger than the mean tension and torque during the installation. This is not a good method for tightening of a critical joint. Operator discretion is used in terms of the achieved tightness of the joint. Associated errors could be even larger than that for hand spanner.

Torque Wrench:

Using a torque wrench a known amount of torque will be applied to the joint. Due to uncertainties in the torque tension relationship even the best calibrated torque wrench can give errors of ±35% if the attention is not given to control the parameters affecting the torque tension relationship. Even with the best control of these parameters errors up to ±30% are not uncommon in field situations. Please refer to case studies presented in our web site www.ajaxfast.com.au.

There are pneumatic or/and hydraulic nut/bolt drivers with a torque limit that will function as a calibrated torque wrench. Other than the larger amounts of torque that these type of devices can provide there is no difference in the error in the achievable tension.

Torque Controlled Bolt:



Torque control bolt has a special feature at the end of the bolt which will be used to tighten the bolt. The tightening device will hold on to the nut and the bolt is rotated using the feature at the end of the shank. Once the correct pre-set torque value is achieved the drive feature will shear off hence tightening will be stopped. Other than applying a reasonably controlled torque this has the added advantage of easily identifying an already tightened bolt.

This method provides slightly better reliability in achieving desired tension than the calibrated torque wrench due to the controlled manufacturing of the bolts and nuts.

Turn of the Nut Method:

Another commonly used method of tightening bolts is the "turn of the nut" method. This method in fact is the recommended method by Australian Steel Codes AS4100. In this method the nut is tightened to a "snug tight" position and then tighten a further fraction of a turn depending on the joint geometry. However, the standard does not specifically define the "snug tight" position. According to the theory, the "snug tight" position is where a step change in the gradient of the torque vs angle curve occurs.

Torque angle signature:

In order to carry out the "turn of the nut" method with any accuracy a torque sensor and an angle encoder shall be used. Then by calibrating on the desired joint with a direct tension measurement device the required nut rotation after the snug tight position can be determined. This will then provide a method of tightening with some degree of accuracy. However, for tightening group bolted joints such as slew ring bolts this method may not be suitable. Snug tight position for one bolt may change with the tightening of the remaining bolts hence making this method more cumbersome and not reliable.

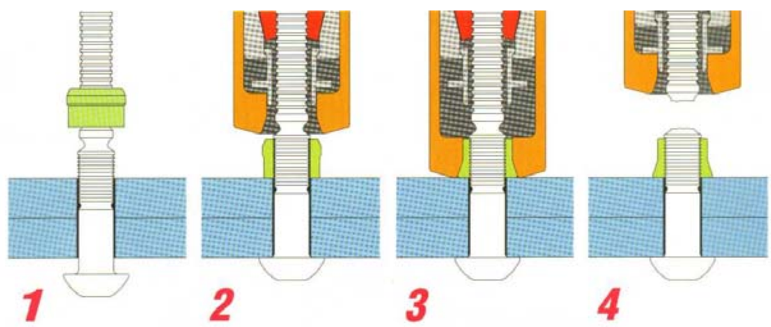
Load Indicating Washers (LIW)

Load Indicating Washer (LIW) is another common method of assuring desired tension. Again this method will not give satisfactory results for tightening slew ring bolts or any group bolted joints as the firstly tightened bolts will become loose when tightening the subsequent bolts. LIWs are capable of indicating the tension only in their first tightening.

Hydraulic Bolt Tensioning

Hydraulic Bolt tensioning is relatively popular in heavy industries due to its simplicity. However, when using this method, the bolt tension is known only when the hydraulic pressure is applied (by measuring the hydraulic pressure). Once the hydraulic pressure is removed and the load is transferred from the jack to the nut, bolt and the tightening flanges the applied tension on the bolt is somewhat relaxed. In one experiment carried out by AFI on a large rock crusher showed that at a 8bar hydraulic pressure applied on three M64 Flange bolts resulted in a 80 -90% of proof load initially and then relaxed to 50 – 56% proof load once the pressure is removed. It was found that the relaxation is a function of bolt/nut size, number of threads engaged, and the joint dimensions among other parameters. However, it was not possible to establish a firm relationship with the applied hydraulic pressure and the final bolt tension.

Direct Bolt Tensioning:



This method is very similar to Hydraulic Bolt tensioning method. However, in this method instead of using the hydraulic pressure to measure the tension the bolt has a end feature that will break off at the correct pre-set tension. Also the nut will be swaged in position at the same time. This system is developed and marketed by Huck® Fasteners.

Due to apparent reasons this system will also suffer from the same joint relaxation issues discussed under hydraulic tensioning. Furthermore, as the nuts are not threaded and swaged in position no further adjustment in tension is not possible. This may lead to some issues in group bolted joints where the tension on previously tightened bolts will be relaxed once the remaining bolts are tightened.

Heating the bolts:

When a bolt is heated it will be enlarged and elongated. If the nut is tightened while the bolt is still hot with respect to the joint, as the bolt cools down a tension will be generated on the bolt. By careful calculation of joint geometry, bolt geometry and material properties it is possible to calculate a temperature to which the bolt need to be heated in order to achieve a desired tension. The assurance of uniformity of the temperature and the measurement of temperature of the bolt is a challenging task. This is a very cumbersome method of achieving tension and as can be expected the accuracy and reliability is somewhat questionable.

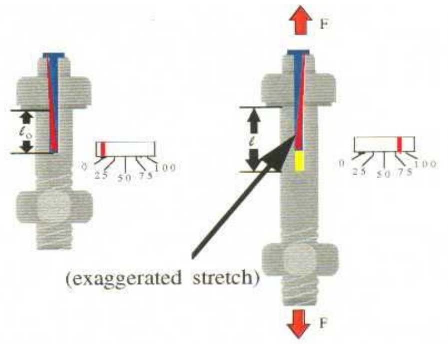
This method is not very suitable for the application with high tensile bolts. The tempering temperature for high tensile bolts is around 400 °C. If heated above this temperature the mechanical properties of the bolt material will be changed. It is very difficult to assure that any point on the bolt will not pass this temperature.

Ultrasonic Measurement:

An ultrasonic pulse is sent through the bolt and the flight of time is measured. As this time is related to the length of the bolt as well as the tension (stresses) this is used as a mean of measuring the bolt tension. Unfortunately, it is just not the bolt tension and the elongation that will cause changes in time of flight. Temperature, nature of reflective surfaces, material constitution, material geometry, interface between the ultrasonic sensor and the bolt, etc., will also have a significant impact on the accuracy of the measurement. As a result a certain level of attention and know how is required to achieve an accurate reading. A properly calibrated instrument can measure the bolt tension with a reasonable reliability and accuracy. This is therefore used only in crucial applications. The accuracy of this system may be 5 – 15%.

Mechanical Direct Tension Indication:

There is a number of mechanical direct bolt tension indicating devices available in the market. Rotabolt®, Maxbolt ®, GE-Bolt to name a few. These products use the elongation of the bolt due to tension to drive an indicator device.



In Rotabolt® it is a rotating knob. The bolt is designed to carry a certain tension. Once this pre-determined tension is achieved the knob cannot be rotated. If the bolt become loose the knob can be rotated again. Although this indicates as the tension reaches the pre-determined value it is not capable of showing possible increased tension due to tightening of other bolts in the joint. Also the bolt can only be used to achieve a pre-set tension value.

In Maxbolt® the elongation of the bolt is coupled to a movement of an indicator. In a typical bolt the total length of travel of the indicator is only a few millimeters while the indicator itself is approximately 0.5mm wide. This will obviously limit the accuracy of the tension reading.
There is another product developed by GE Electrical Distribution & Control in Selmer, Tenn., USA. This product uses a plunger attached to the bottom of a pre-drilled hole in the shank of the fastener coupled with an optically dense fluid to indicate the deformation. The change in color from Red to black will indicate the tension from lose to tight. However, the method does not allow enough resolution and accuracy in terms of a particular tension value.

Although, the sensitivity and resolution of these device are not very attractive they should provide a mean of controlling the bolt tension. The cost of these products is relatively high and therefore may limit them to very crucial applications.

An accuracy of 5 – 10% may be achieved with these systems.

Strain Gauging:

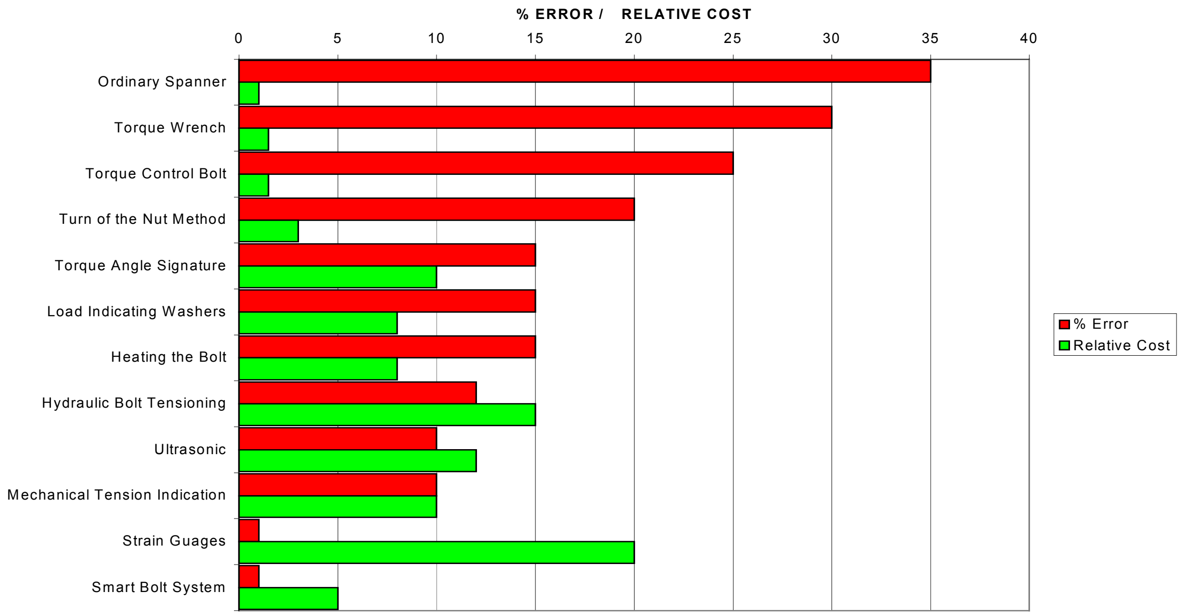
Direct strain gauging of the bolt shank will produce accurate tension measurements. However, this has to be done on a bolt by bolt basis and require external instrumentation for measurement. This method is very fragile and contains external wiring and use of cumbersome measuring equipment. The bolts need to be handled carefully due to the fragile nature of the strain gauges. These bolts resemble technology of load cells. In general, these are very expensive and mostly used for experimental purposes. The accuracy of this method may be 2 – 5%.

SMARTBOLT™ System:

AFI has developed and marketing a robust, economical and easy to use direct tension measuring system SMARTBOLT™ that can provide an accuracy of 1 – 3%. Unlike any other direct tension indicator devices SMARTBOLT™ can accurately measure the tension of the bolt at any time. It can also track the continuous changes in tension due to dynamic operating loads. The elongation of the bolt due to direct tension is measured using a highly sensitive and accurate strain measuring device that will be connected to the head of the bolt via a neodyne rare earth magnet. The sensor element installed in the bolt is robust and no wired connections are necessary. The hand held sensor can investigate any number of SMARTBOLT™ just by placing it on the head of the bolt.

Please refer to our web site for further information on this system.

A comparison of various bolt tightening methods available today in terms of their accuracy and relative cost is shown in the Figure below. It is obvious that the cost of the system goes up with the increasing accuracy. However, in critical applications cost of a failure will totally out weigh the cost of a reliable fastening system.



Another factor that affects the bolt tension is the joint temperature. Especially if the joint is made of dissimilar materials the differential thermal expansion of the bolt and joint materials will cause variations in the bolt tension. Even if the bolts are tightened accurately to the desired tension value if the joint is subject to temperature variations the working tension on the bolt may change. It is not possible to theoretically estimate these changes to a sufficient accuracy. Only direct tension measurement with continuous monitoring capability will provide the engineer with the real time working tensions on these bolts.

Ajax Fastener Innovations (AFI) offers a consulting service to assist in the design of bolted joints in specific applications. AFI has the experience; test equipment, analysis methods, and analysis tools developed over many years, to provide our customers with a greater level of confidence in the design of critical joints. Furthermore, AFI is dedicated to developing fastening solutions that cater for the specific needs of industry.

If you need any further assistance please contact us.