Controlled tightening

Just take control

By EGA Master

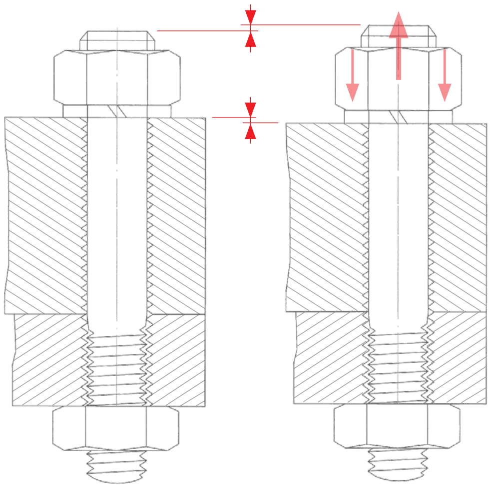
A world developing exponentially fast generates growing security needs and advanced technology applications.

That is why EGA Master has developed its torque checking QC wrenches.

They register the original tightening torque of the fastener by means of an innovative system that registers the torque at the same time that the fastener starts to turn, thanks to its rotation angle sensor (registering the torque's value when it detects a turn of 3º).

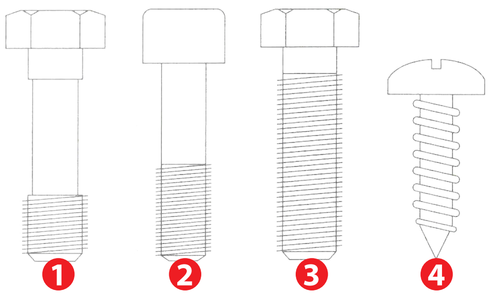
Glossary

Threaded join: joining of parts through threaded elements.



Join **not-tightened** Join **tightened**

Thread: helical edge of a screw (outerthread) or of a nut (innerthread), triangular, square or blunt section, formed on a cylindrical core, the diameter and pitch of which are standardized... Threads are characterized by their profile and pitch, in addition to their diameter.

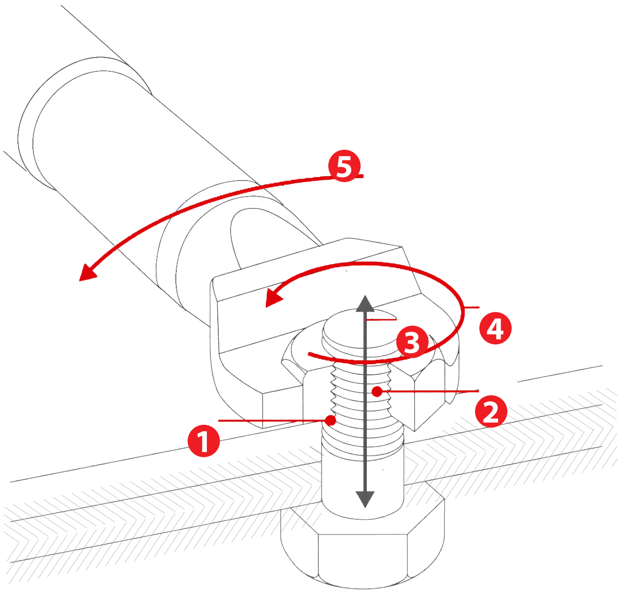


1. **Tension** bolt
2. Machine screw, **Allen head**
3. Machine screw, **hexagonal**
4. **Self-tapping** screw

Threaded element tightening: fixing through the application of tension by means of threaded elements.

Axial tightening tension: Tension generated in the longitudinal threaded element when tightening. It is measured in Units of Force by Area (Kg/mm^2, N/mm^2, lb/ft^2...)

Glossary



1. **Underhead friction**
2. **Thread friction**
3. **Clamping force**
4. **Sum (∑) of all torques**
5. **Tightening force**

Torque or moment: Pair of forces in a system formed by two forces to parallel to each other, of the same intensity or module, but of opposite senses.

Applying a **pair of forces** to a body results in rotation or twisting. The magnitude of the rotation depends on the value of the forces forming the pair and the distance between the two, called the **pair arm**.

A couple of forces is characterized by his moment. The *moment of a pair of forces*, *M*, is a vector magnitude which module the product of any of the forces multiplied by the distance (perpendicular) between them, *d*. That is to say: $M=F_1d=F_2d$

Tightening torque: Torque applied to threaded elements in the tightening. It is measured in Units of Distance Force (Nm, Kgm, lb-ft, lb-inch, ...)

Tightening angle: The angle at which the threaded element is rotated to achieve the desired tightening (usually after an initial torque tightening). It's measured in degrees.

N.m

Newton metres

The most common unit of measure used to describe torque is the newton metre. This unit is part of the international system of units (SI) for physical quantities.

One newton metre corresponds to one joule of energy and is the mechanical work performed when one newton is applied over a distance of one metre.

ft.lb

Foot pound

The foot pound is the Anglo-American unit of measure used for torque, or moment. Originally, it was called the pound foot (lbf. ft), but was renamed to avoid confusion with the unit of energy of the same name. One ft.lb corresponds to approx. 1356 joules which is the energy required to raise one pound avoirdupois one foot.

in.lb

Inch pound

The inch pound (lbf.in) is also an Anglo-American unit of measure. One in.lb corresponds to 0.11298483 joules, which is the energy required to raise one pound one inch (2.54cm).

1
TIGHTENING FUNCTION

Screwed tightening or threaded joint's function is to fix joining structural elements, transmitting motor or braking forces, or sealing containers of liquid and gas containment. It represents one of the most common procedures in assembling or assembling parts.

The fundamental element is the screw, which can be described as a threaded bolt equipped with a head that serves for drag and anchoring. There are also other threaded elements for the joint (bolts, nuts...)

2

WHY IS ITS CONTROL IMPORTANT?

To ensure proper fixation of the elements during the service time required by each application, the threaded joining elements must be carefully sized, as they must withstand high clamping forces and static and dynamic stress.

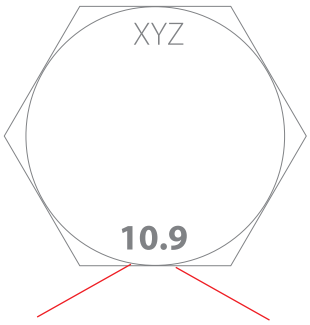
The goal for the joined pieces is to behave as if they were a single piece, with no relative movements.

To do this, an adequate tension force must be applied to the joint, which is achieved when the screws are tightened.

The correct selection of tightening elements not only dimensions needs to be considered, but also in terms of their mechanical strength. The mechanical resistance categorization code includes 2 elements.

The first of the numbers indicates the tensile strength (multiplied by 100, gives us the result in N/mm^2); the second number indicates the elastic limit (multiplied by the first number and by 10, gives us the result in N/mm^2).

In the example below, the tensile strength would be 1000N/mm^2 (10x100) and the elastic limit would be 900N/mm^2 (9x10x10).



Tensile stregth
1st number x 100 N/mm^2
10 x 100 N/mm^2
1000 N/mm^2

Yield point
1st number x 2nd number x 10 N/mm^2
10 x 9 x 10 N/mm^2
900 N/mm^2

Service life, performance, operating costs and safety are affected if the appropriate axial stress is not applied during tightening.

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3
TIGHTENING PHYSICS

In threaded joint assembly regardless of method used, the purpose is used to obtain a clamping force that keeps the components assembled. The screw acts as a spring to the tension that generates such force and that is in balance with the parts it assembles, compressing them.

The rigidity of the screwed joint is determined by the force that the screws exert in the axial direction on the parts it joins. This force is characterized by the tension that is generated on the threaded shaft (bolt, screw) when tightened.

The optimum strength for each joint is determined by the function that it must perform, so the sizing, hardness and strength of the screws will depend on it.

Although the magnitude to be controlled is the axial stress of the screw, it is difficult and very expensive to measure. Therefore, there are several methods of controlled tightening, depending on the criticality of the measurement, the investment capacity and the time available for the operation.

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4

CONTROLLED TIGHTENING METHODS

These are the controlled tightening methods that exist:

TIGHTENING METHOD	DESCRIPTION	PROS AND CONS
TORQUE CONTROL	- It is the most common method - Control is done through the applied torque	- It is an easy-to-apply, fast and reasonably cost-effective method - As the length of the screw does not affect the torque, standardization is simple. - The dispersion of the applied axial stress is large, and the optimum efficiency of the screw is not achieved
ANGLE OF ROTATION	- The tightening is controlled through the angle - The screw is tightened at a specific an-gle from an ini-tial reference torque value	- It is possible to reach the point of plastic deforma-tion of the screw, so the disper-sion of the tension is small and the effi-ciency of the tightening good - Because the elastic limit is exceeded, there are limi-tations to applying addi-tional loads or performing re-tightening - It is difficult to calculate the necessary angle
TORQUE GRADIENT	- Uses the property that when exceeded the yield limit, the deformation grows rapidly. The torque and tightening angles are detected with electrical sensors, the elastic limit is calculated by computer, and the tightening is done in its vicinity	- Reduced axial stress dispersion and high tighte-ning efficiency - The equipment is very expensive - Not feasible in field work
MEASURING ELONGATION	- The elongation of the screw generated by the tightening is measured - Can be done with micrometer or ultra-sonic	- The dispersion is very low, so the preci-sion of the tightening on the elastic limit is possible - The efficiency of tightening is high - Additional loads or re-tightening may be applied - The cost of both equipment and times is high - Low viability in high-tightening operations
BY LOAD	- Stretches the screw to the defined vol-tage - It is the applied load that controls the tightening	- The axial stress is directly controlled - No torque pressure is generated in the screw - Both charging equipment and screws are special - High cost of both
BY WARMING UP	- Heat the screw to elongate it - The tightening is temperature controlled	- No space or force required for tighten-ing - No relationship between temperature and axial stress - Difficult control of the temperature setting - It requires prevention measures for handling hot parts

5
TORQUE TIGHTENING

Torque tightening is an indirect method of approaching the voltage limit, and therefore optimal fixation is not ensured. However, its ease, speed and reduced cost make it the most used method of controlling bolted joints.

The relationship between the applied torque and the axial stress achieved is affected by numerous factors, such as:

1. Materials
2. Friction between joining surfaces
3. Thread
4. Dimensions
5. Temperature
6. Lubrication

The accuracy of the applied torque depends on:

1. The accuracy of the torque wrench used
2. The system with which the key tells us that the pair has been reached
3. Operator's experience and skill

Today, most industries pay close attention to key accuracy and calibration and ignore the human factor and the key system itself.

However, the factors that introduce the most error in the actual applied torque are the latter two, since the accuracy of the keys usually hovers around 2-6% error, while the operator's skill and drive system can exceed 10-15% error.

Therefore, and in order to achieve the closest to the design tightening, it is essential both the training and training of the operators, as well as the selection of wrench systems that facilitate the application of a correct effective pair.

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5.1 Mechanical trigger or click wrenches

These are keys that, when reaching the selected torque, release the trigger head briefly by clicking, telling the operator to stop applying force. Operator's unawareness at the exact time at which the torque will be reached, joined to the short shift that the click system introduces, it is difficult for the operator not to exceed the applied torque, even with experience.

5.2 Mechanical sliding wrenches

Once the fixed torque is reached, the system releases the wrench from the handle where the effort is applied, and therefore the overtightening. The drawbacks are the cost and robustness of the mechanical system. Therefore, only low torque range wrenches are manufactured with this system.

5.3 Digital wrenches

The wrench indicates the torque that the user is applying and informs both by means of lights and beeps that selected torque is being reached, so the operator is aware on when to stop applying force on the wrench. They also allow to record historical data for verification, issuance of certificates, etc.

In any of the versions, there are variants:

Prefixed wrenches: They have a prefixed torque, which the user cannot modify. It is useful in those applications when always the same troque needs to be applied, since it eliminates the possibility of human error in the selection of the correct torque.

Interchangeable heads: They allow to exchange the heads between square drive ratchet, open end or ring spanners, depending on the application to be made. In operations where access is complicated or where the tightening varies frequently, it is the most flexible and versatile solution.

6
ANGLE TIGHTENING

The tightening torque is not directly related to the axial tension of the screw. Torque depends on the friction between nut/screw head and joining surfaces, and therefore the same torque will exert different tension on the threaded shaft depending on the dimensions, material, temperature and lubrication of nut, head te screw and support surface.

In this method a preliminary torsional torque called ***pre-torque*** is applied. A certain angle is then applied. Such ***pre-torque*** and angle values must be specified and are unique for each assembly, although the specified angle is usually 90º, and their tolerance can range from 5o to 15o depending on the assembly's own design and the means to perform it.

With this method usually the screw lengthens a little beyond the elastic limit, reaching the plastic zone, that is to mean the permanent deformation.

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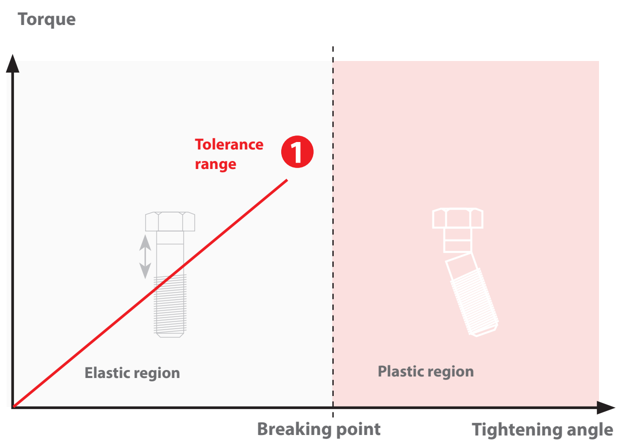
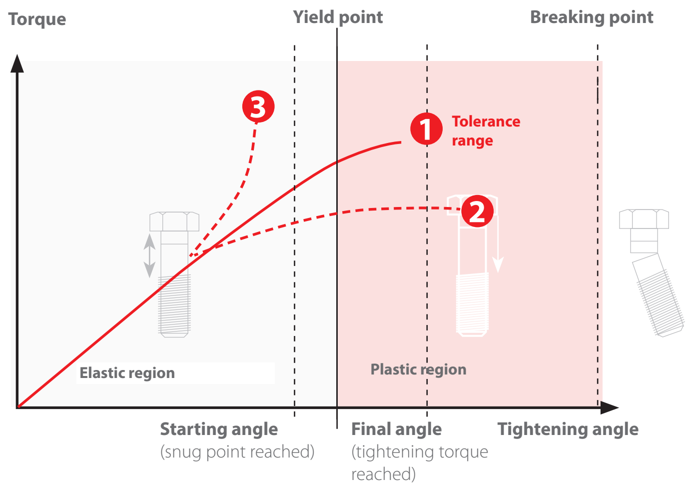
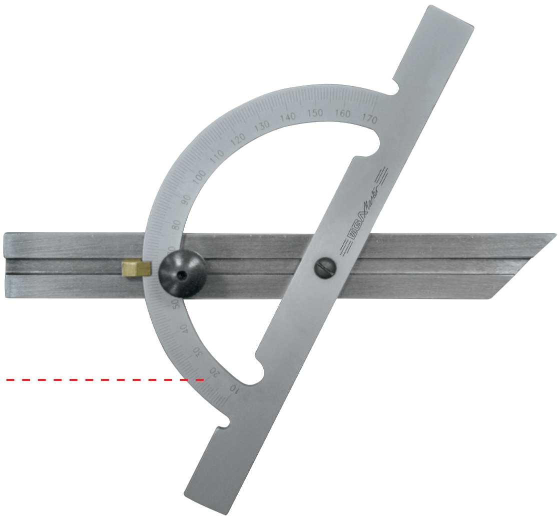
Tightening angle method with a **standard fastener**



Tightening angle method with a **tension bolt**



A deformation is considered as permanent when, accoding to ISO 868, such deformation or elongation becomes an additional 0.2% from the original screw length. This method can be applied to any assembly in which the screw is the weakest element of the assembly and it is generally used in safety assemblies. In this method, the clamping force tends to be constant and it is generally independent of friction and torsional torque dispersion. One point to be considered is that usually screws already assembled with this method, when disassembled cannot be reusable, that is to say, they have to be discarded.



6.1 Angular measurement by goniometer

Once the ***pre-torque*** is applied, the angle to be applied is measured with a goniometer, marked, and the nut is tightened to the indicated angle.

6.2 Digital angular measurement

There are digital torque wrenches that allow both the ***pre-torque*** (torque) to be applied as well as immediately apply the corresponding angle. First it warns us both of the moment when we achieve the pre-torque value, and then tell us the moment when the desired angle is obtained. It is probably the fastest and most accurate means for angular torque tightening, with an assumed cost.

7

TIGHTENING TORQUE CHECK

There are several variables that may cause tightening to fail to perform properly:

1. **Human error:** By forgetting to tighten one or more consecutive nuts
2. **Human error:** By selecting the inappropriate torque, or is confused with scale.
3. **Poorly calibrated key**

Therefore, in processes where a large number of controlled tightening is performed, and/or by many people, it is usually advisable to carry out a statistical check on the tightenings performed, in order to ensure that the tightenings have been performed correctly.

The method is based on applying a torque to a nut already tightened until it moves and registering the torque to which the nut has moved.

The procedure is complex, and its accuracy low, because there are numerous conditions that distort the measurement.

1. **The user's dexterity and sensitivity** in detecting when the nut moves
2. **Every nut tightened by a torque of X, will require one of X+Y to get it moved** (since not only the static torque to which we pressed before must be overcome, but also the dynamic force to be able to move it)

All this makes existing control methods a reliable method of knowing if the nut had been tightened to a torque close to the required... but not in order to get a precise data of the torque to which it was tightened. Basically, it serves to know whether the operator had tightened the nut to values close to what he had to, or not.

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It can be done by applying a torque of over-tightening, or a torque of loosening.

7.1 Dial torque wrenches

The user tightens (or loosens) the nut, looking at the torque that is shown on the dial. When the user notices the nut moving, it ceases to apply torque. The reference needle will show the maximum torque value that the user has applied. The indicated torque will inform us if the original torque was close to the designed one.

7.2 Digital torque control wrenches

As with dial torque wrenches, the user tightens (or loosens) the nut until it moves. The wrench itself detects movement (3º) and records the torque that was being applied when the movement happened. It is a more accurate procedure than dial, as the human component is removed. They also have traceability of the applied torque, as well as a peak value. It has 4 measurement units.

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8
CALIBRATION AND ERROR CORRECTION

Calibration is the process of comparing the values obtained by a torque wrench with the corresponding measurement of a reference (or standard) pattern.

According to the International Bureau of Weights and Measures, calibration is "an operation which, under specific conditions, establishes in a first stage a relationship between the values and measurement uncertainties provided by corresponding standards and indications with the associated measurement uncertainties and, in a second step, uses this information to establish a relationship to obtain a result of the measure from an indication."

It can be inferred from this definition that to calibrate an instrument or a standard it is necessary to have a higher precision (pattern) that provides the conventionally verifiable value, which will be used to compare it with the indication of the instrument is being calibrated.

Calibration is to measure the difference between the measurement offered by the measuring instrument, and the actual measurement instrument. A calibration certificate is that certificate that tells us (secures or certifies) the differences between measurement and reality.

Correcting the error is "adjusting the instrument" so that the differences between measurement and reality are less than a certain percentage (typically the percentage of design error).

The main reasons that may lead to the need for calibration of measuring instruments are that:

• A specific time period has expired.

• A certain volume of usage has been exhausted (working hours)

• When an instrument has received a strong shock or vibrations that may have caused it to discalibre

• Higher than acceptable temperature changes

• Provided that the observations obtained are questionable

The calibration process starts with the design of the measuring instrument to be calibrated. The design has to be

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able to "support calibration" through its calibration interval. That is to say, the design has to be able to take measures that fall within the "engineering tolerance" when used in environmental conditions for a reasonable period of time.

The exact mechanism for assigning tolerance values varies by country or industry type. In general, measurement equipment manufacturers assign tolerance in measurement, suggest a calibration interval, and specify the normal range of use and storage. Having such a design increases the likelihood that current measuring instruments will behave as expected.

The next step is to define the calibration process. Selecting the standard(s) or standards is the most visible part of the calibration process. Ideally, the standard should have less than a quarter of the measurement uncertainty that is given by the device to be calibrated. The process is to choose a standard that meets the above standard on measurement uncertainty and to use it to compare its measurement with that of the calibrated apparatus, after choosing a standard with a tighter degree of uncertainty and repeating the previous operation.

This process is repeated until the standard is reached with the greatest possible certainty available in the calibration or metrology laboratory. This process establishes the traceability of the calibration.

It must be said that this process of calibration by standards is almost always preceded by a visual inspection of the instrument, where it is checked that the instrument does not present any physical damage that can be seen with the naked eye.

The results of this inspection are commonly referred to as the ***"as-found"*** inspection data (instrument data as they have been found). Normally the entire calibration process is commissioned from a single specialized technician who will be responsible for documenting that the calibration has been successfully completed.

The process explained above is a difficult and expensive challenge. The cost of technical support for ordinary equipment is generally approximately 10% of the original

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purchase price on an annual basis. Other more exotic and/or complex machinery may be even more expensive to maintain.

The extension of the calibration program exposes the core beliefs of the organization involved. The integrity of the organization can easily be seen in question depending on the calibration program that has been established. In general, it is a question of each machine in an organization having a specific calibration process planned for it.

For example, if a company has multiple machines of the same one, older machines will be used for less suffered jobs and will therefore require limited calibration.

Machines that are often used and on which the production process depends, will instead have to be calibrated more regularly and with quite tight tolerances. On the other hand, each machine must be calibrated only in relation to the operation/work it develops. This means that although the machine can actually do many more jobs than it actually does in the production process, you only have to calibrate the work you actually do actively. All other calibration processes will be unnecessary.

This process of choosing and designing the calibration process must be performed for all the basic instruments that are present in the organization.

In order to improve the quality of calibration in favor of external organizations accepting the results obtained, it is desirable that the corresponding measures be easily convertible to the **International System of Units.** The action of establishing traceability can be done by making a formal comparison with a standard that may be directly or indirectly related to national, international or certified reference materials.

Quality management systems require an effective metrology system that includes formal, periodic and documented calibration of all measuring instruments. ISO 9000 and ISO 17025 establish that these actions have high traceability and indicate how to quantify.

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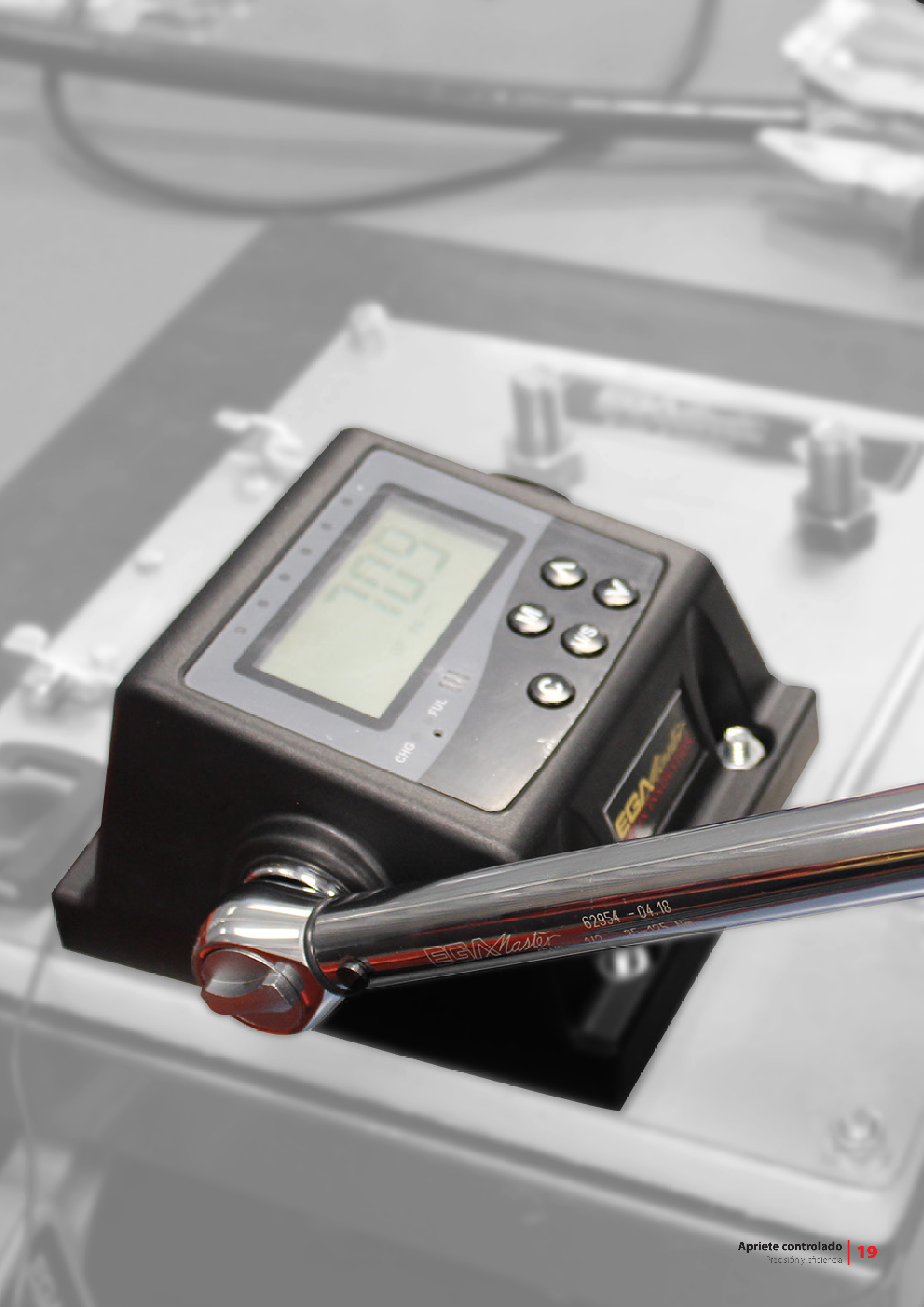
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9

REGISTRATION AND COMMUNICATION OF DATA

Another increasingly important aspect is the recording of data. It is not enough to assure the customer that the tightening has been performed, but increasingly the customer demands the demonstration that it is.

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9.1 MANUAL REGISTRATION

Tightening values are written down in paper, and then transferred to a certificate. Its drawbacks are:

1. Human error both when registering and moving data to the certificate.
2. The operator is demanded a new task that interrupts the tightening process, which affects the concentration and may cause the tightening sequence to fail.
3. Inefficient process.

9.2 WIRED DATA COMMUNICATION

It is the torque wrench itself that saves the tightening data, and then the user is able to download it to the computer via a cable. It is a system that prevents human error, as well as interruption in tightening. The only drawback is that the operator has to periodically move to a computer to download the data, and that, if the wrench suffers some problems, the stored data could still be lost without downloading.

9.3 REMOTE DATA COMMUNICATION

It is the key itself that records the values and transmits them in real time to the computer, so that there is data integrity, there is no risk of data loss, and the operator should only be focused on performing the tightening correctly.

9.4 TWO-WAY REMOTE DATA COMMUNICATION

There is a new digital key mode that is not only able to communicate the registers of remotely applied torques, but it is also able to adjust on the wrench the torque to which a nut must be tightened following the instructions of the tightening process that the production system tells you. In this way, the operator will not be able to make a mistake in selecting the correct torque, or the correct unit of measurement... reducing possible errors, and releasing the operator so that he can focus 100% of his attention on making a tightening as accurate as possible.

10
OTHER FEATURES

Today it is possible to add production functionalities thanks to the development of additional software and hardware that interacts with the data and records generated by the digital dynamo keys:

1. Prevent progress in processes until ensuring that the tightening stakes have been performed correctly
2. Prevent erroneous tightening
3. Automate tightening registration certificates (for client)
4. Relate keys and tightening tools through geolocation
5. Etc

11
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