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Method for documented tightening or retightening a screw connection

The invention relates to a method for the documented tightening or retightening of a screw connection consisting of a threaded bolt and a nut screwed onto the threaded bolt and supported against a support, by using an axially operating tensioning device comprising a cylinder housing, an exchangeable bush arranged in the cylinder housing which at the end thereof facing the threaded bolt is provided with an internal thread and able to be screwed onto the threaded bolt, and at least one piston which is able to be moved axially in the cylinder housing and able to be impinged with hydraulic pressure and by way of which the exchangeable bush is axially entrainable, and furthermore using a rotary drive for the nut, which as a module is attachable externally to the cylinder housing, and a process control unit provided with a documentation module.

Hydraulically powered, axially operating screw-tensioning cylinders are known from DE 101 45 847 A1 or WO 03/024670 A1, from WO 2008/092768 A2, from WO 2010/054959 A1 or from DE 10 2015 104 133 A1. For tensioning or retensioning a screw connection consisting of a threaded bolt and a nut screwed onto the threaded bolt and supported against a support, an exchangeable bush of the tensioning cylinder is first screwed to the free end of the threaded bolt that projects beyond the nut. For this purpose, the exchangeable bush is provided with a corresponding internal thread. The exchangeable bush is arranged within a hydraulic cylinder housing and surrounded by at least one piston. The piston, as part of a hydraulic piston-and-cylinder unit, can axially entrain the exchangeable bush, as a result of which the threaded bolt is temporarily axially elongated. While the latter is elongated, the nut is retightened, i.e. locked, by means of a rotary drive arranged externally on the cylinder housing.

In the screw-tensioning cylinder according to DE 101 45 847 A1 or WO 03/024670 A1, this rotary drive is designed as a geared electric motor and has a rotary encoder which detects the rotation angle of the rotary drive. Furthermore, there is a computer device which computes, from the detected rotation angle in combination with the known thread pitch of the threaded bolt, the elongation of the latter and the resultant pre-tensioning force of the threaded bolt, and displays this to the user. Furthermore, it is disclosed as a method step to first tighten the nut, before commencing the tensioning process, with a sufficient torque in order to compensate for settlement processes. The rotary encoder is reset to zero only once this has taken place.

The operating parameters used in a screw-tensioning process, and general data pertaining to the screw case, are typically not systematically detected and documented. Such data can be, for example, the brand, the sort or the type of the threaded bolts or nuts, as well as tightening and torque values of the bolts and/or nuts. Often, suitable devices for detecting and documenting such data are also absent in the screw-tensioning devices. The documentation is however important, specifically in screw connections in which permanent checking is necessary and in which a sufficiently strong screw connection has to be proven for safety reasons. This is the case, for example, in reactor vessels or storage vessels with hazardous chemical or nuclear products.

It can be problematic if it is not known to the operator of the tensioning device in which range the required or ideal hydraulic pressure and the associated tightening pressure, or the tightening force, for the bolt to be braced lies. The values can vary depending on the type, brand or size of the bolt. This can lead to insufficient or excessive longitudinal forces being prevalent after the tightening of the bolt therein. Apart from these factors influencing the operational safety, the quality and precision of the tightening or retightening procedure can also be compromised if the bolts are not tightened with the ideal tensioning force and thus the longitudinal force in the threaded bolt does not correspond to the optimum. The use of an unsuitable torque when locking the nut is also disadvantageous.

It is known, for example from DE 10 2012 105 654 A1, to unequivocally identify screw connections by scanning an individual identifier, preferably a barcode identifier, present on the screw connection. The identifier thus determined is stored in the form of data in a documentation module. The screw connection is longitudinally elongated by means of the tensioning device by axial tension at the end of the thread of the threaded bolt, and also the tightening force applied in the process and/or the hydraulic tightening pressure are/is stored in the documentation module. During the longitudinal elongation, the nut is locked while using a manual torque wrench, for example.

The invention is based on the object of enabling specific documentation for the individual screw case when tightening or retightening high-strength screw connections by means of axially operating tensioning devices and of improving the quality and reproducibility of the screwing process in this way.

In order to achieve this object, a method having the features of Patent Claim 1 is proposed. The method comprises the following steps:

a) tightening the nut by means of the rotary drive with a tightening torque which is at least required for the nut to bear on the support without a gap;

b) longitudinally elongating the screw connection by activating the tensioning device by exerting axial tension on the thread end of the threaded bolt that protrudes beyond the nut;

c) further tightening the nut by means of the rotary drive while maintaining the longitudinal elongation, detecting a rotation angle covered during this further tightening by means of a rotation angle sensor in the process;

d) computing the lengthening of the threaded bolt associated with the longitudinal elongation from
    - the rotation angle covered and
    - the thread geometry of the screw connection;

e) computing a longitudinal force F in the threaded bolt from
    - the lengthening,
    - the bolt diameter and
    - the bolt length;

and is characterized in that the computed longitudinal force, conjointly with an identifier identifying the screw connection, is stored in the documentation module, in that the tightening and the further tightening of the nut is carried out with the same tightening torque while exerting a force by means of a hand tool attachable to the rotary drive, in that the torque used when tightening and when further tightening the nut is detected by means of a torque sensor and a corresponding torque value is stored in the documentation module, and in that detecting the torque takes place when tightening and further tightening the nut in the module.
While using this method, important metrics, as are characteristic for the individual screw case, are documented in such a way that the quality of the screw connection achieved remains even retrospectively verifiable. Further, additional data may be of a general type and comprise, for example, the manufacturer code, the brand, the item number, the sort, the type or further physical-technical metrics of the screw connection.

A particular important parameter is the longitudinal force prevalent in the longitudinally deformed threaded bolt after the tightening or retightening of the screw connection, which represents the tension in the bolt. The longitudinal force is a function of the lengthening and thus elongation which is imparted to the threaded bolt during the tension process which is preferably carried out hydraulically.

Therefore, in a first computing step, the lengthening, associated with the longitudinal elongation, of the threaded bolt is computed

- from the rotation angle covered during the locking of the nut

- and the thread geometry of the screw connection.

The rotation angle covered in the process is not necessarily the rotation angle of the nut per se, but can also be another rotation angle that is coupled to the rotation angle of the nut. For example, a gear element of the rotary drive can be detected by means of a rotation angle sensor, or the rotation angle sensor is a constituent part of the hand tool used for tightening the nut, or the rotation angle sensor is integrated structurally in the cylinder housing of the tensioning device.

The thread geometry of the screw connection utilized as a computing parameter in the first computing step is the thread pitch of the thread on the threaded bolt and the nut. This is because a longitudinal dimension, presently thus the size of the longitudinal elongation of the threaded bolt, thus the lengthening of the latter, achieved by the axial tensioning can be computed directly from the two geometric variables rotation angle and thread pitch.

In a second computing step, the longitudinal force acting in the direction of tension in the threaded bolt is then computed, specifically from

- the lengthening of the threaded bolt determined in the first computing step,

- the bolt diameter of the threaded bolt

- and the bolt length.

Here, the bolt length used for the calculation is not the absolute length of the threaded bolt including its enlarged bolt head. Instead, significantly, it is that length on which the threaded bolt is substantially deformed. The parts of the threaded portion of the threaded bolt and, if present, a non-threaded shank portion of the threaded bolt, form the thus significant length. The significant bolt length, used in the second computing step, herein is only that length on the threaded portion and optionally on the shank portion that extends between the bolt head and the nut, likewise having a substantially rigid behaviour. This is because the lengthening during the tensioning process takes place on this longitudinal portion of the bolt.

In order to be able to compute a precise value for the longitudinal force in the threaded bolt, the precision and the reproducibility when retightening the nut is important. This is because there may be settling processes when retightening the nut, above all due to unevennesses on the contact surfaces.

For this reason, a multi-stage approach is taken. In the above method step a), the nut is tightened by means of the rotary drive by way of such a tightening torque, preferably while the tensioning device is operated in a preliminary stage at an only minor pressure of, for example, 50 bar hydraulic pressure, so that settling processes are largely eliminated and the nut comes to bear on the support largely without a gap.

Only once the largely gap-free contact between the nut and the support has been ensured does the activation of the tensioning device at the actual hydraulic system pressure of, for example, 1500 bar, and thus the longitudinal elongation of the screw connection by exerting a high axial tension on the thread end of the threaded bolt, take place in step b). While maintaining the high axial tension, further retightening or locking of the nut, and detecting a rotation angle, covered during this further retightening, by means of the rotation angle sensor, then take place in step c) by means of the rotary drive.

In order to keep the risk of erroneous operations by the user as low as possible, the same tightening torque is used for the further retightening of the nut according to step c) as in the first retightening of the nut according to step a). Renewed setting of the torque wrench is not necessary in this way.

The computing steps d) and e) are performed based on the measures according to the method steps a) to c). In the process, the lengthening of the threaded bolt associated with the longitudinal elongation is computed

- from the rotation angle covered during the further retightening of the nut

- and the thread geometry of the screw connection.

In a second computing step based thereon, the longitudinal force in the threaded bolt is computed from

- the lengthening,

- the bolt diameter

- and the significant bolt length.

Furthermore, the longitudinal force in the threaded bolt thus computed, conjointly with an identifier identifying the screw connection, is stored as a data set in the documentation module in a further method step.

The identification of the individual screw connection is performed by scanning, and the result of the identification is stored in the documentation module. Additionally, a date, a time, a project number or other data can be assigned to the identified screw connection in the documentation module. These data are also conjointly stored in the common data set and are identifiable at any time in this way.

The data are preferably stored in a common file which is saved on a server, an external computing unit or in a data cloud. The same applies to the applied tightening force and/or to the hydraulic tightening pressure used, as well as to the torque actually applied when retightening the nut. The data are stored as a common data set in the documentation module. This documentation enables each individual screw connection to verify the quality and state even retrospectively verifiably at any time, for instance for certification purposes.

The torque actually applied when retightening the nut by means of the rotary drive is detected metrologically, and the measured value is documented in the documentation module. A torque sensor arranged in the rotary drive is used for detecting the torque.

According to a design embodiment of the method, after the identification of the screw connection, a tightening force and/or a tightening pressure stored in a database is proposed to the user by the process control unit before the operator activates the tensioning device. For this purpose, the process control unit can access an electronic database. In the latter, optimal or recommended values and/or value ranges for tightening forces and/or hydraulic tightening pressures are stored for the type of the respectively identified screw connection.

However, if the operator should prefer another tightening force and/or another tightening pressure by virtue of his/her individual experiences, the operator does not agree to the parameter proposal by the process control unit. The operator then manually enters a value and then activates the tensioning device. This can also be documented in the documentation module.

According to another design embodiment, after identification of the screw connection, a tightening force and/or a tightening pressure which is stored in the database as being optimal for exactly this type of threaded connection is selected by the process control unit, and the hydraulic pump of the screw tensioning cylinder is adjusted automatically, thus in a self-acting manner, to this pressure. The hydraulic pump, which is connected to the piston chamber of the screw tensioning cylinder by way of corresponding supply and discharge lines, is thus actuated to a specific pump pressure by signals from the process control unit.

A hydraulically driven tensioning device is used for carrying out the method. This hydraulically driven tensioning device comprises a cylinder housing designed as a hydraulic cylinder, an exchangeable bush which is arranged in the cylinder housing and at the end thereof facing the threaded bolt is provided with an internal thread and can be screwed onto the threaded bolt, and at least one piston which is axially movable in the cylinder housing and is able to be connected to a hydraulic supply and through which the exchangeable bush is guided centrally and by means of which the exchangeable bush is axially entrainable.

The cylinder housing or a component rigidly connected thereto is supported on that support, for example a machine element, against which the nut is also supported. The method described is advantageous above all when using a hydraulic tensioning device. This is because an enormous longitudinal force is created in the threaded bolt during the hydraulic length elongating of the threaded bolt. Determining and documenting this longitudinal force is therefore of particular importance for judging the quality of the tensioning process, even retrospectively. There is always the risk of the threaded bolt, which is under a high tensile load, being ripped out or jumping out under very high tightening forces and/or tightening pressures. Therefore, the correct selection of tightening forces and/or tightening pressures suitable and/or optimal for the identified screw connection is advantageous, be it with or without clearance by the user.

In the preparation of the tensioning process, the exchangeable bush can be screwed onto the threaded bolt using the hand tool used anyway for locking the nut. Screwing the exchangeable bush onto the bolt on the one hand and locking the nut on the other hand are in this case performed with one and the same hand tool, for example a torque wrench with a ratchet mechanism.

The identifier of the screw connection is scanned by a sensor, in particular a barcode scanner. This can be an optical sensor. The sensor can be an integrated constituent part in the screw tensioning cylinder, a constituent part of the hand tool used or of a separate apparatus.

The sensor, or barcode scanner, can in particular be arranged externally on or internally in the screw tensioning cylinder.

However, arranging the sensor on the hand tool can have advantages in terms of the flexibility and the ease of handling of the scanner. This is because the hand tool is compact and of a lesser weight than the heavy tensioning device.

A mobile computer, a correspondingly programmed tablet computer or a smartphone serves as the process control unit. It is important that the control unit comprises a display unit and an input unit. The display unit and the input unit can be conjointly implemented in a touch screen, for example. The sensor for identifying the identifier is connected to the process control unit for transmitting signals.

The tensioning device and/or the hand tool can be provided with a transceiver unit which is connected to the process control unit for transmitting signals, by way of which transceiver unit the exchange of data with the process control unit takes place. In this case, the process control unit also has a transceiver unit.

The transceiver units can be signal-connected to one another in a wireless or wired manner. WLAN, radio or UMTS are suitable, for example. Almost any modern form of wireless signal transmission may be suitable.

A common application program which is installed in a computer unit, for example, is advantageously present for the process control unit and for the sensor recording the identifier.

Locking the nut takes place by means of the rotary drive arranged externally on the tensioning device. The rotation angle sensor can be a constituent part of the rotary drive. The rotation angle sensor detects a rotation angle which is covered during the tightening or locking, respectively.

Alternatively, the rotation angle sensor can be arranged on the hand tool, thus the torque wrench. Such an arrangement is considered in particular if the hand tool is configured as a ratchet with a corresponding rotary mechanism.

The detected angular value can be stored in the documentation module, for example. For this purpose, the rotation angle sensor is connected to the process control unit for signal transmission by way of the application program, for example, as a result of which the detected rotation angle value is available for mathematical evaluation by the process control unit. In this evaluation, the achieved elongation and thus lengthening of the threaded bolt is computed from the rotation angle value covered during the locking of the nut in conjunction with the known thread geometry of the screw connection, thus in particular the thread pitch on the threaded bolt and on the nut. This computed value of the lengthening can be stored in the documentation module and thus be permanently documented.

Once the rotation angle has been covered so as to correspond to the lengthening of the threaded bolt and the nut is locked by way of a predefined torque until the nut bears without a gap, it is ensured in this way that the threaded bolt has been longitudinally elongated with the correct force, and that the tensile force, or longitudinal force, prevalent in the elongated threaded bolt has a specified value, at least lies in a corresponding value range, which is optimal for the respective type of bolt.

The tensile force or longitudinal force in the threaded bolt is mathematically determined from the previously computed lengthening of the threaded bolt, the bolt cross section and here in particular the diameter of the latter, and from the bolt length covered by the elongation.

The documentation module comprises a memory and/or a database. The data pertaining to the identification and the tightening and locking procedure can be stored therein and later accessed, in particular the applied tightening force and/or the tightening pressure, the actually applied manual torque, and the tensile force, i.e. longitudinal force, prevalent in the threaded bolt by virtue of the tensioning process.

Further details and advantages of the method are derived from the description hereunder of an exemplary embodiment illustrated in the drawing in which:

Fig. 1 shows an illustration of a threaded bolt which has a nut and braces two machine parts;

Fig. 2 shows in a perspective view a first embodiment of a hydraulically operating threaded bolt tensioning device, applied so as to be co-aligned with the threaded bolt and supported on the upper machine part. Moreover illustrated is a hand tool when screwing an exchangeable bush onto the free end of the threaded bolt;

Fig. 3 shows the same tensioning device as in Fig. 2, during the axial tensioning process;

Fig. 4 shows the same tensioning device as in Fig. 2 and Fig. 3, during the retightening of the nut with the hand tool;

Fig. 5 shows in a perspective view a second embodiment of a hydraulically operating threaded bolt tensioning device including the attached hand tool;

Fig. 6 shows the same threaded bolt tensioning device without the hand tool and

Fig. 7 shows the items as per Fig. 5 in a perspective exploded illustration.

The screw connection 1 reproduced in Fig. 1 comprises a threaded bolt 2 which is composed of an enlarged bolt head 2A and a shank and threaded portion, and a nut 3 which is screwed onto the threaded portion. The screw connection 1 presently braces two machine parts 5, 6 in relation to one another. Apart from the threaded bolt 2 and the nut 3, further construction elements may also be a constituent part of the screw connection 1, for example a further nut on the side of the machine part 6 to be braced that faces away from the nut 3. Additional washers may also be a constituent part of the screw connection 1.

An identifier 7 is permanently arranged on the threaded bolt 2. By way of example, this is shown in Figure 1 by means of a barcode 7 which is arranged on the end side 8 of the threaded bolt 2, or of the end of the threaded bolt, respectively. The barcode 7 is first scanned by a sensor. The barcode 7 here is detected prior to the actual tightening or retightening. This is because the information obtained by scanning is the basis for identifying the exact type of the screw connection 1, and thus a precondition for determining the screwing data important for the tensioning process.

The sensor, or scanner, can be arranged on a hand tool 10 (Fig. 2) which is configured as a torque wrench having an adjustable torque trigger value, for example. As described hereunder, the hand tool 10 is anyway required in the context of the method. Alternatively, the sensor, or scanner, can be part of a mobile computer unit, for example of a tablet computer, of a smart phone, or of an associated mobile computer unit. The sensor may be a camera, for example. A separate scanning module which is used exclusively for scanning the identifier 7 may also be used. Arranging the sensor, or scanner, directly in or on the tensioning device 11 described in more detail hereunder is also possible. When the tensioning device 11 is in this instance attached to the bolt 2 to be braced, the barcode 7 is simultaneously scanned in the process.

The screw connection 1 is longitudinally elongated by means of the tensioning device 11 by an exclusively axial tension on the free thread end 15 of the threaded bolt 2. Specific method parameters for the elongation process can be proposed to the operator for the respectively identified type of the screw connection 1 by means of a process control unit 23, for example by accessing data sheets with corresponding values that are saved in a database. The operator can then confirm or reject the parameters proposed to him/her in this way.

However, an automated method with a pressure adjustment at a hydraulic pump 22 of the tensioning device 11, carried out automatically by the process control unit 23, and subsequent automatic activation of the tensioning device is preferred.

The screw connection is tightened or retightened by the hydraulically operated tensioning device which operates purely axially. This is illustrated in Figures 2 to 4.

When the tensioning device 11 is activated, the threaded bolt 2 of the screw connection 1, on its shank and threaded portion, is longitudinally elongated by axial tension on the thread end of the threaded bolt 2 that protrudes beyond the nut 3. The tightening force applied in the process and/or the tightening pressure applied by means of the hydraulic system is preferably automatically stored in a documentation module 24, specifically irrespective of whether this is a tightening force manually set by the operator, or a tightening force and/or a tightening pressure which is automatically set by the process control unit 23 and has been obtained from the values in a database.

While the predefined pretensioning force is exerted for a certain time on the threaded bolt 2 in the longitudinal direction of the bolt in the case of an activated tensioning device 11, the nut 3 of the screw connection 1 can be tightened or retightened. This is performed by means of the hand tool 10, which is therefore configured as a torque wrench with a trigger function and with a ratchet mechanism. The tightening torque actually applied when locking the nut 3 will be stored in the documentation module 24, the latter preferably being a constituent part of the process control unit 23.

An exchangeable bush 12, which is arranged centrally in the tensioning device 11 so as to be movable longitudinally, at its lower end is provided with an internal thread 13. Prior to the start of the tensioning process, the exchangeable bush 12 by way of this internal thread 13 is screwed onto the thread end portion 15 of the threaded bolt 2 that protrudes beyond the nut 3. This screwing procedure is preferably carried out with the hand tool 10. During the actual tensioning process, the exchangeable bush 12, which has been screwed onto the threaded bolt 2 in this way, is placed hydraulically under axial tension, as a result of which the threaded bolt 2 is elongated in the longitudinal direction. In the process, a tensile force, or longitudinal force, of the magnitude F is prevalent in the threaded bolt.

Owing to the temporary longitudinal elongation of the bolt 2, the lower side of the nut 3 is released from the support 5A in such a way that the nut 3 can be rotated with relatively little rotational resistance and be retightened or locked until bearing on the support 5A without a gap again. This is performed with a torque, or tightening torque, predefined by corresponding setting on the torque wrench 10.

A rotating sleeve 16, which is arranged about the nut 3 and entrains the latter in a form-fitting manner, is driven by a rotary drive 17. The rotary drive 17 is either a constituent part of the tensioning device 11 per se, or it is located in a module 30 which is attached externally to a cylinder housing 18 of the tensioning device 11, as illustrated.

The hydraulic tensioning mechanism is enclosed by the pressure-tight cylinder housing 18. The rigid downwards continuation of the cylinder housing 18 is formed by a support tube 19 that surrounds the nut 3. The support tube 19 can be integral to the cylinder housing 18, or alternatively be a component which is separate from the cylinder housing 18, for example a component which is attachable to the latter. The support tube 19 is open on its lower side and is supported on a fixed support 5A, for example the upper side of the machine part 5, said support 5A forming the counter bearing in the tensioning process. In the method described herein, the counter bearing 5A is that machine part 5 against which the nut 3 is supported by way of its lower side.

A gear which operates on the rotating sleeve 16 through an opening in the support tube 19, is a constituent part of the module that forms the rotary drive 17. The rotary drive 17, or the gear thereof, conjointly with the rotating sleeve 16, therefore form the device for locking the nut 3.

The torque required for locking is applied by moving the hand tool 10, which is configured as a ratchet wrench and attachable to the rotary drive 17, in a reciprocating manner until a set torque is reached and either triggers a torque limiter or emits a torque signal. Of course, the nut 3 can expediently be rotated only as long as the tensioning device 11 is active.

A hydraulic connector 20, by way of which the hydraulic working chamber 21 of the tensioning device 11 is connected to the external hydraulic supply in the form of the hydraulic pump 22 so as to be controlled by a valve, is located laterally on the cylinder housing 18. The external hydraulic supply, including the hydraulic pump 22, can be arranged on a trolley.

A piston 25 is arranged in the hydraulic cylinder so as to be movable in the longitudinal direction and sealed in relation to the cylinder internal wall. The piston 25 is lifted by feeding hydraulic pressure into the hydraulic working chamber 21 of the cylinder. This can take place, for example, counter to the force of a strong spring which impinges the piston 25 from above and serves as a piston restoring spring and impinges the piston 25 directly with a force which urges the piston 25 to maintain its initial position in which the hydraulic working chamber 21 is at its minimum.

The piston 25 surrounds the exchangeable bush 12 in an annular manner. The piston on its internal periphery is provided with an encircling step 27 which, facing away from the support, forms an entrainment surface on which the exchangeable bush 12 is supported by way of a radially enlarged portion 28. In this way, the exchangeable bush 12 is axially entrainable by the piston 25.

The exchangeable bush 12 on its bolt-proximal end is provided with the internal thread 13 for screwing onto the threaded bolt 2. The exchangeable bush 12 on its upper end is provided with a socket 30 on which a polygon of the hand tool 10 can engage so as to rotate the exchange bush 12 in the preparation of the tensioning process and in the process screw the exchange bush 12 onto the threaded bolt 2.

When the hydraulic pump 22 according to Fig. 3 feeds pressurized fluid at the pressure P into the working chamber 21, the piston 25 is lifted and axially entrains the exchangeable bush 12 which is supported on the entrainment surface 27. The threaded bolt 2 is longitudinally extended and a spacing or gap ΔL is formed between the lower side of the nut 3 and the support 5A.

The pressure P provided by the hydraulic pump 22 is automatically set by the process control unit 23, specifically based on the type of the screw connection 1 identified by scanning, and based on the pressure or force values predefined for this type. Alternatively, the values can be set manually by the operator.

The retightening, i.e. locking, of the nut 3 is performed on the rotary drive 17 which is arranged in the form of the module 30 externally on the tensioning device 11, while using the torque wrench 10 which is set to a predefined trigger value. For this purpose, the torque wrench is attached to a drive polygon 29 on the module 30, or on the rotary drive 17.

At least one of the gear elements of the rotary drive 17, or alternatively the torque wrench 10, is provided with a rotation angle sensor. The latter detects a rotation angle which is covered overall in the process of tightening the nut 3 until the torque wrench 10 is triggered. The detected rotation angle can either be the rotation angle of the nut 3 per se, or another characteristic rotation angle which is performed by one of the rotating gear elements of the rotary drive or which is performed by the torque wrench 10.

The angular value detected in this way is first stored for the purpose of further evaluation, to which end the rotation angle sensor is connected to the process control unit 23 for transmitting signals, so that the detected rotation angle value is available in the process control unit 23 for the purpose of further processing and evaluation.

In this evaluation, the residual elongation and consequently lengthening of the threaded bolt 2 is computed from the rotation angle value covered during the locking of the nut 3 in conjunction with the known thread pitch of the threaded bolt 2 and the nut 3. This value of the lengthening can be stored and in this way permanently documented in the documentation module 24.

If the predefined rotation angle, corresponding to the lengthening of the threaded bolt 2, is covered and the nut 3 thereafter is locked with a predefined torque until the latter bears on the support 5A without a gap, it is ensured that the threaded bolt 2 has been tightened with the correct force and that the value F of the longitudinal force prevalent in the threaded bolt 2 has a specific optimal size, or lies in a corresponding size range. This is because the longitudinal force F prevalent in the longitudinally deformed threaded bolt 2 after tightening or retightening the screw connection represents the tension in the bolt 2. Said longitudinal force is a function of the lengthening that is imparted to the threaded bolt 2 during the tensioning process.

In a first computing step, the lengthening of the threaded bolt 2 associated with the longitudinal elongation is computed, specifically from

- the rotation angle covered while locking the nut 3

- and the thread geometry of the screw connection 1.

The rotation angle covered in the process is not necessarily the rotation angle of the nut 3 per se; instead, this can also be another rotation angle coupled to the rotation angle of the nut 3. For example, a gear element of the rotary drive 17 can be detected by means of a rotation angle sensor, or the rotation angle sensor is integrated structurally in the cylinder housing of the tensioning device 11, or the rotation angle sensor is integrated structurally in the torque wrench 10.

The thread geometry of the screw connection utilized as a computing parameter in the first computing step is the thread pitch of the thread on the threaded bolt 2 and the nut 3. This is because a longitudinal dimension, here thus the size of the longitudinal elongation of the threaded bolt 2 achieved by the axial tensioning, thus the lengthening of said threaded bolt, can be computed from the two geometric variables rotation angle and thread pitch.

The longitudinal force F acting in the tensile direction in the threaded bolt 2 is then computed in a second computing step, specifically from

- the lengthening of the threaded bolt 2 determined in the first computing step,

- the bolt diameter of the threaded bolt 2

- and the bolt length.

The longitudinal force F can be computed as follows, for example. Here, E is the elasticity modulus of the bolt material, A is the size of the bolt cross section, L is the characteristic bolt length, and dL is the bolt lengthening.

$$F = \frac{dL}{L} x (E x A)$$

The bolt length utilized for computing the longitudinal force F in the threaded bolt 2 is not the absolute length of the threaded bolt 2 including the radially enlarged bolt head 2A. Instead, the length along which the threaded bolt is substantially deformed is decisive. The characteristic bolt length which is relevant to this extent is formed by parts of the threaded portion of the threaded bolt 2 and, if present, a non-threaded shank portion of the threaded bolt. Here, the characteristic bolt length utilized in the second computing step is that length of the threaded portion and optionally of the shank portion which extends between the bolt head 2A and the nut 3 which likewise behaves in a substantially rigid manner. Appreciable lengthening only takes place on this longitudinal portion during the tensioning process.

In order to be able to compute a precise value for the longitudinal force F in the threaded bolt 2, the precision when retightening the nut 3 is important. This is because there can be settling processes when retightening the nut, above all due to unevennesses on the contact surfaces. For this reason, a multi-stage approach is taken. In order to eliminate erroneous measurements due to the settling processes as far as possible, the tensioning device 11 in a preliminary stage is first activated only at a relatively minor hydraulic pressure of, for example, 50 bar. Once this preliminary pressure is achieved, the nut 3 in the method step a) by means of the rotary drive 17 is tightened with such a predefined tightening torque that the nut 3 comes to bear on the support 5A largely without a gap and settling processes are eliminated.

Only once the largely gap-free contact between the nut and the support has been ensured by means of this preliminary stage does the actual tensioning process by activating the tensioning device 11 and thus longitudinally elongating the screw connection 1 take place in step b). In the process, the significantly higher system pressure of, for example, 1500 bar, is set in the tensioning device 11. While maintaining the axial tension exerted herein, the further retightening, or locking, of the nut 3, and the detection of a rotation angle covered during this further retightening by means of the rotation angle sensor, then take place in step c).

The further retightening of the nut 3 after step c) is carried out with the same tightening torque as the first retightening of the nut previously in the preliminary stage according to step a).

The torque actually used when retightening the nut 3 is metrologically detected by means of the torque sensor, according to Fig. 4. The torque sensor here is integrated in the torque wrench 10. The corresponding torque value in terms of signals is transmitted from the torque wrench 10 to the process control unit 23 by way of the signal path 31, and is likewise stored in the documentation module 24. The rotation angle value is transmitted by way of the signal path 32.

The transmission of the data and measured values detected during the tightening or locking of the nut 3 to the process control unit 23 takes place by way of the signal paths 31, 32 and preferably by way of wirelessly operating transceiver units. The covered rotation angle, the actually applied torque, and the computed longitudinal force F in the threaded bolt 2, conjointly with the individual identifier of the screw connection 1, are stored in the documentation module 24 of the process control unit 23. These variables can be stored in data tables or in parameter files, for example, in the documentation module 24. The documented data can be accessed and exported for example later for the purpose of proof.

A second embodiment is reproduced in Figures 5 to 7. The same reference signs here refer to components which correspond to the likewise denoted components in the first embodiment.

The difference in comparison to the first embodiment lies in the module 30 attached to the tensioning device 11. Not only the rotary drive 17 of the locking device, but also the torque sensor which detects the torque used when tightening and further tightening the nut, is integrated herein. The module 30 is provided with a signal connector 33 by way of which, apart from the rotation angle value, also the torque value is transmitted to the process control unit 23.

In this way, only one signal path 34 on which the rotation angle detected on the rotary drive 17, as well as the detected torque, is transmitted to the process control unit 23 is required in total in the second embodiment. This can take place by means of a signal cable, or wirelessly by means of corresponding transceiver units on the module 30 on the one hand, and by way of the process control unit 23 on the other hand.

The covered rotation angle, the actually applied torque, and the computed longitudinal force F in the threaded bolt 2, conjointly with the individual identifier of the screw connection 1, are also stored in the documentation module 24 of the process control unit 23 in the second embodiment.

List of reference signs

1	Screw connection
2	Threaded bolt
2A	Bolt head
3	Nut
5	Machine part
5A	Support
6	Machine part
7	Identifier, barcode
8	End side
10	Hand tool, torque wrench
11	Tensioning device
12	Exchangeable bush
13	Internal thread
15	Thread end
16	Rotating sleeve
17	Rotary drive, locking device
18	Cylinder housing
19	Support tube
20	Hydraulic connector
21	Working chamber
22	Hydraulic pump
23	Process control unit
24	Documentation module
25	Piston
27	Step
28	Radially enlarged portion
29	Drive polygon
30	Module
31	Signal path
32	Signal path
33	Signal connector

34	Signal path
F	Longitudinal force
ΔL	Length, gap
P	Pressure

Patentkrav

1. Fremgangsmåde til dokumenteret spænding eller efterspænding af en skrueforbindelse (1) bestående af en gevindbolt (2) og en herpå påskruet møtrik (3), der støtter sig mod et underlag (5A), ved anvendelse af en aksialt arbejdende spændeanordning (11) omfattende et cylinderhus (18), en heri anbragt udskiftelig bøsning (12), som i den ende, der vender mod gevindbolten (2), er forsynet med et indvendigt gevind (13), og kan skrues på gevindbolten (2), og mindst et stempel (25), der kan bevæges aksialt i cylinderhuset (18) og kan påføres et hydraulisk tryk (P), og af hvilket den udskiftelige bøsning (12) kan medtages aksialt, og desuden ved anvendelse af et drejedrev (17) til møtrikken (3), der kan sættes som modul udvendigt på cylinderhuset (18), og en processtyringsenhed (23) forsynet med et dokumentationsmodul (24), hvor fremgangsmåden har følgende trin:

a) spænding af møtrikken (3) ved hjælp af drejedrevet (17) med et tilspændingsmoment, som mindst er påkrævet til møtrikkens spaltefrie kontakt med underlaget (5A);
b) ved aktivering af spændeanordningen (11) længdestrækning af skrueforbindelsen (1) ved udøvelse af aksialt træk på den gevindende (15) af gevindbolten (2), der stikker ud over møtrikken (3);
c) under opretholdelse af længdestrækningen fornyet spænding af møtrikken (3) ved hjælp af drejedrevet (17), herved registrering af en drejevinkel tilbagelagt under denne fornyede spænding ved hjælp af en drejevinkelsensor;
d) beregning af den med længdestrækningen forbundne forlængelse af gevindbolten (2) ud fra

- den tilbagelagte drejevinkel og
- skrueforbindelsens (1) gevindgeometri;

e) Beregning af en længdekraft (F) i gevindbolten (2) ud fra

- forlængelsen,
- boltdiameteren og
- boltlængden;

kendetegnet ved, at den beregnede længdekraft (F) lagres sammen med en mærkning, der identificerer skrueforbindelsen (1) i dokumentationsmodulet (24), at spændingen og den fornyede spænding af møtrikken (3) gennemføres med samme tilspændingsmoment under kraftudøvelse ved hjælp af et håndværktøj (10), der kan sættes på drejedrevet (17), at drejemomentet, der anvendes ved spændingen og ved fornyet spænding af møtrikken (3), registreres ved hjælp af en drejemomentsensor, og en tilsvarende drejemomentværdi lagres i dokumentationsmodulet (24), og at registreringen af drejemomentet sker ved spænding og fornyet spænding af møtrikken (3) i modulet.

2. Fremgangsmåde ifølge krav 1, kendetegnet ved, at skrueforbindelsen (1) identificeres ved scanning af en mærkning (7), foretrukket en stregkode-mærkning, på skrueforbindelsen.

3. Fremgangsmåde ifølge et af kravene 1 - 2, kendetegnet ved, at brugeren efter identifikation af skrueforbindelsen (1) får meddelt en tilspændingskraft og/eller et tilspændingstryk, lagret i en database, af processtyreenheden (23), før spændeanordningen (11) aktiveres.

4. Fremgangsmåde ifølge et af kravene 1 - 2, kendetegnet ved, at der efter identifikation af skrueforbindelsen (1) automatisk af processtyringsenheden (23) vælges en tilspændingskraft og/eller et tilspændingstryk lagret i databasen, og at en hydraulikpumpe tilsluttet spændeanordningen (11) automatisk køres til dette tryk.

5. Fremgangsmåde ifølge et af kravene 1 - 2, kendetegnet ved, at der efter identifikation af skrueforbindelsen (1) automatisk af processtyringsenheden (23) vælges en tilspændingskraft og/eller et tilspændingstryk lagret i en database, og spændeanordningen (11) ved anvendelse af de valgte værdier automatisk aktiveres af processtyringsenheden (23).

6. Fremgangsmåde ifølge krav 1, kendetegnet ved, at registreringen af drejevinklen sker ved indretning af drejevinkelsensoren i modulet.

7. Fremgangsmåde ifølge krav 1, kendetegnet ved, at registreringen af drejevinklen sker ved indretning af drejevinkelsensoren på en drejemomentnøgle (10), der kan sættes på drejedrevet (17).

8. Fremgangsmåde ifølge krav 1, kendetegnet ved, at registreringen af tilspændingsmomentet sker ved spænding og fornyet spænding af møtrikken (3) på en drejemomentnøgle (10), der kan sættes på drejedrevet (17).

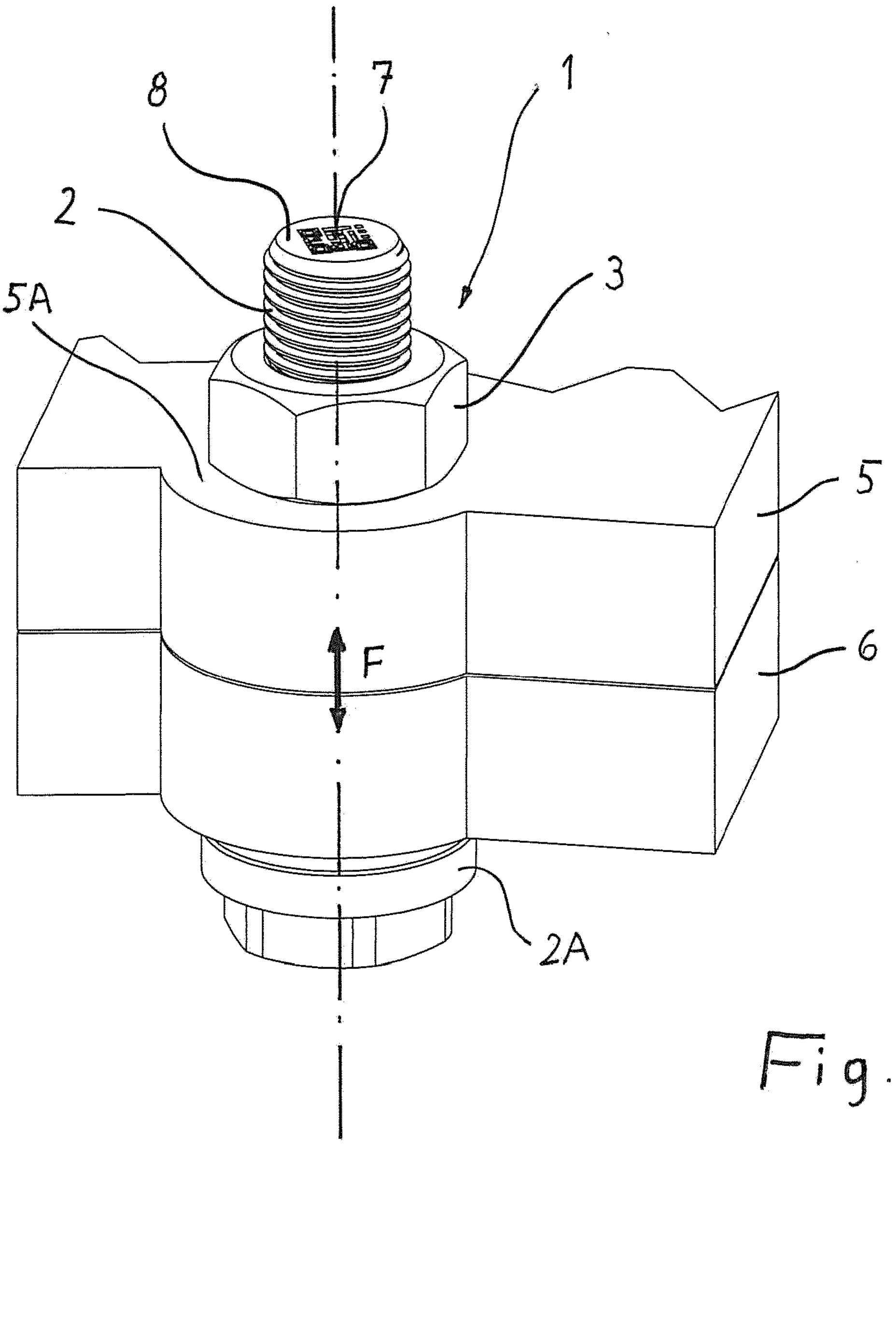

Fig. 1

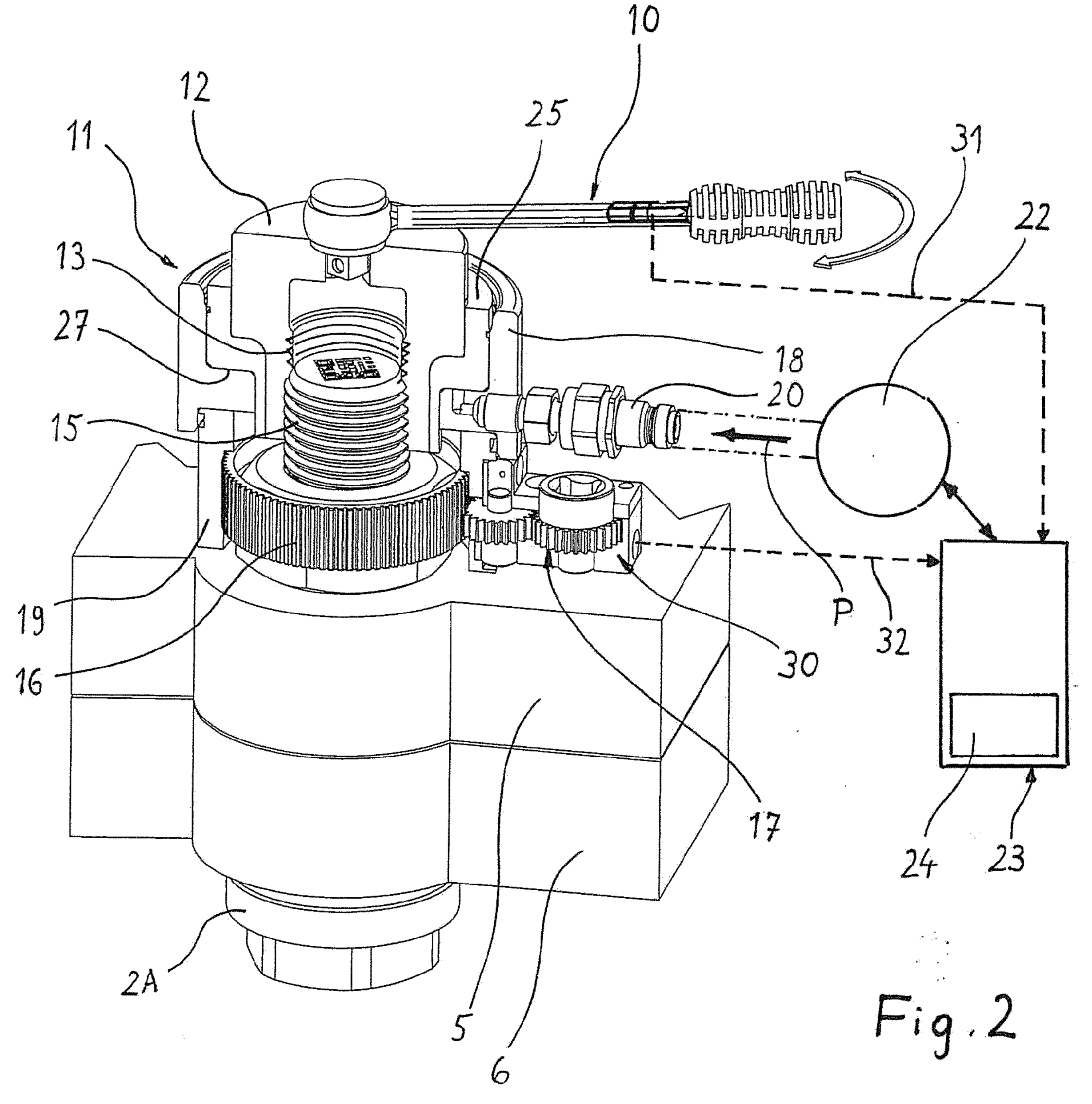

Fig. 2

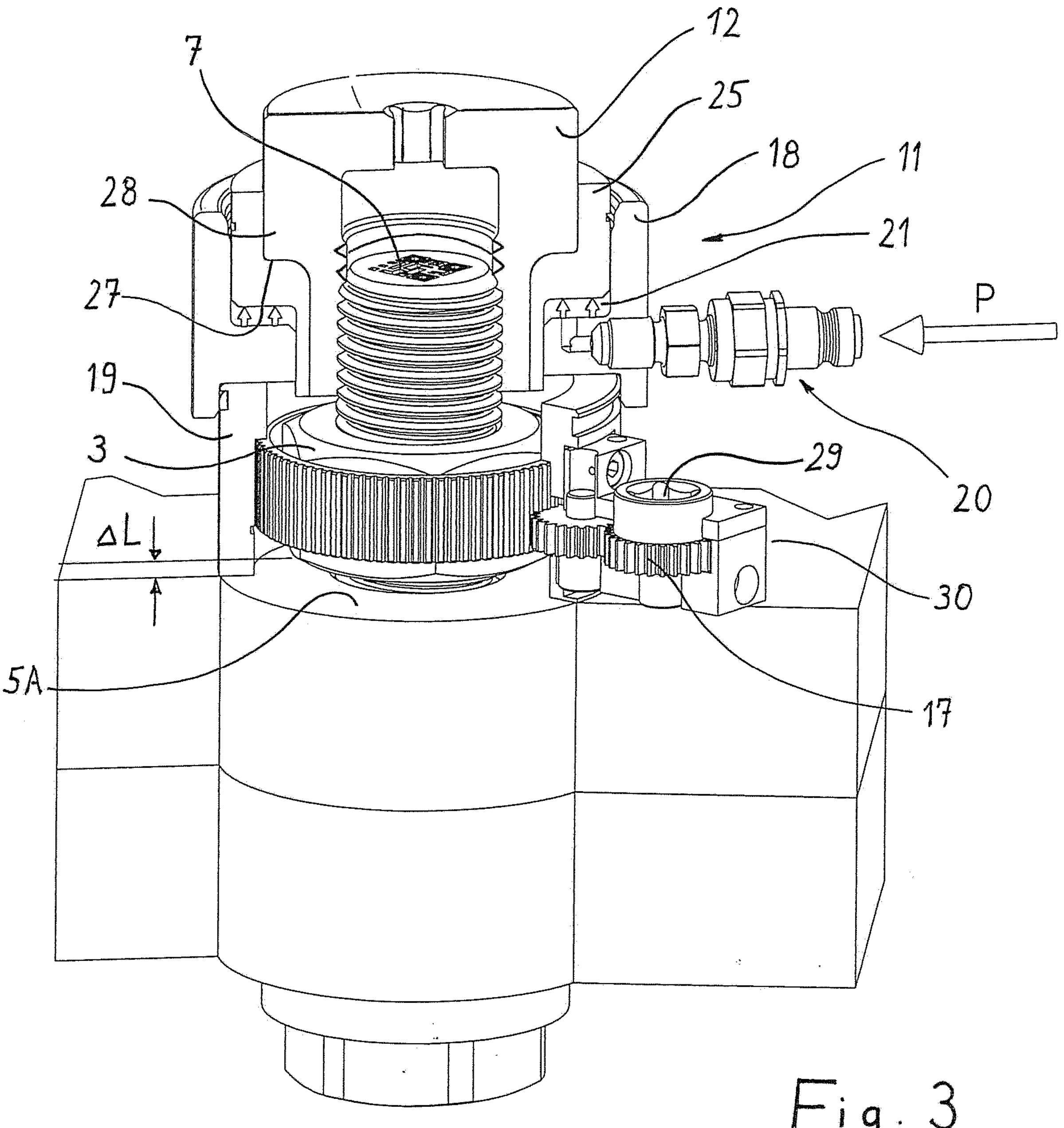

Fig. 3

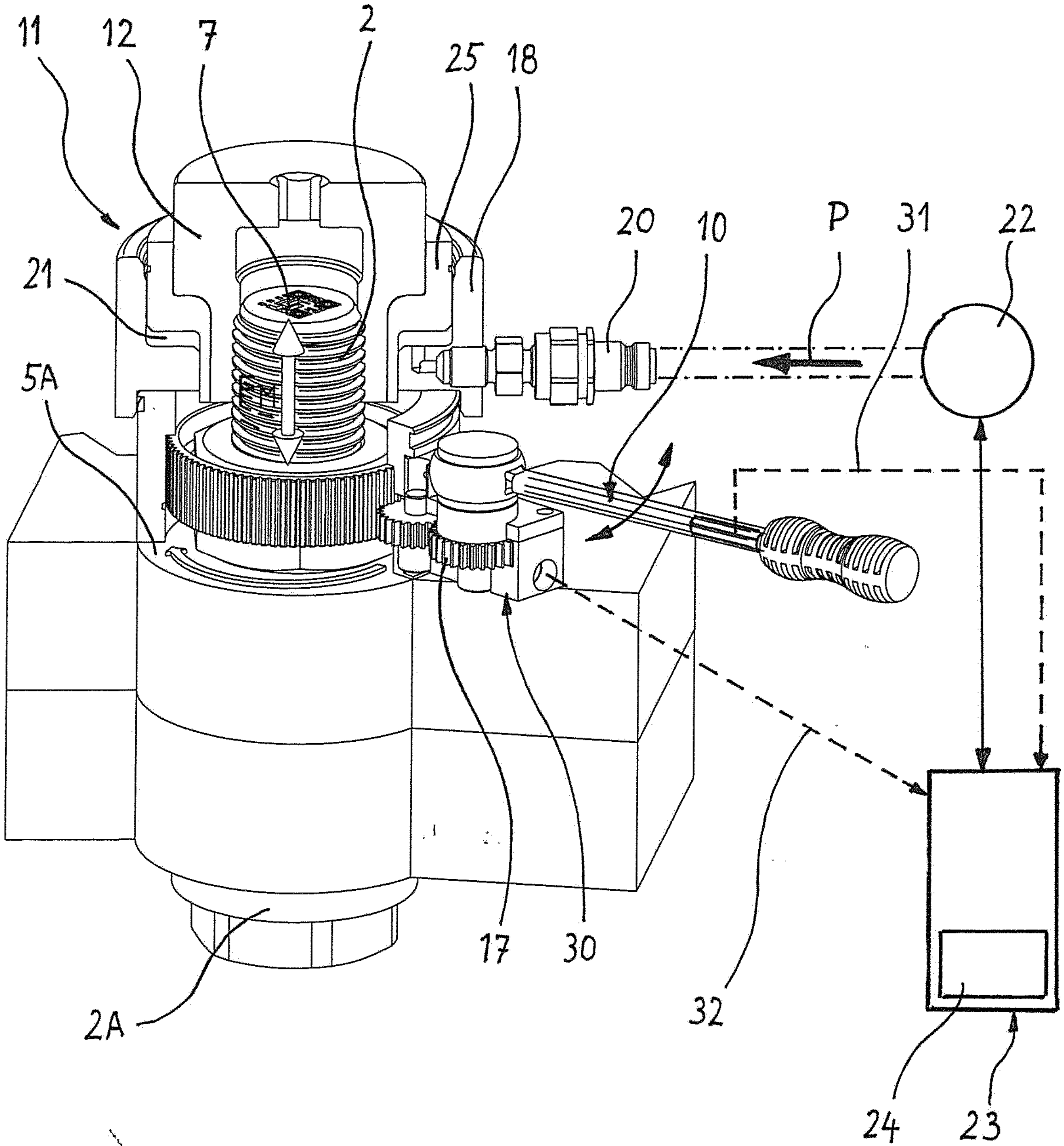

Fig. 4

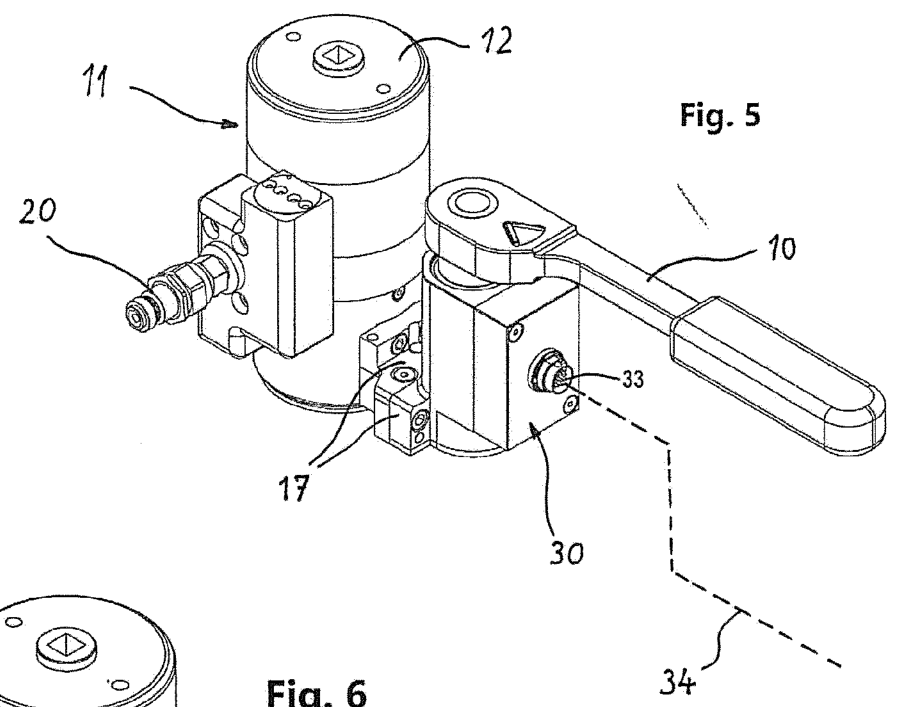

Fig. 5

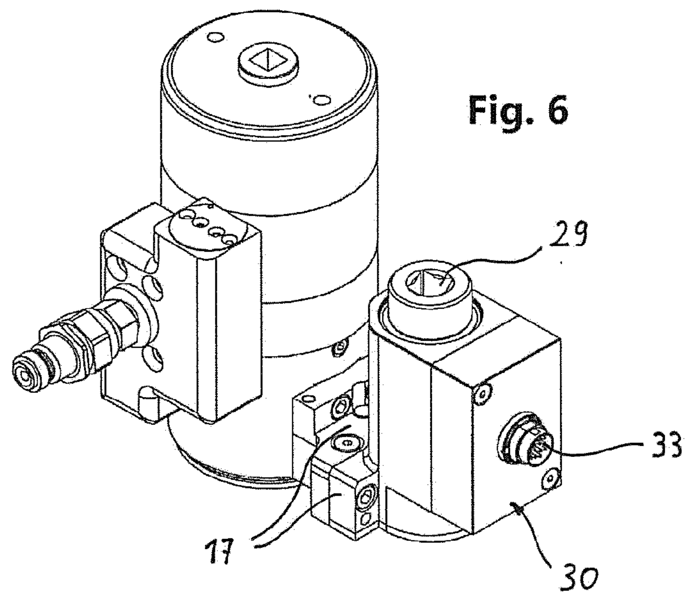

Fig. 6

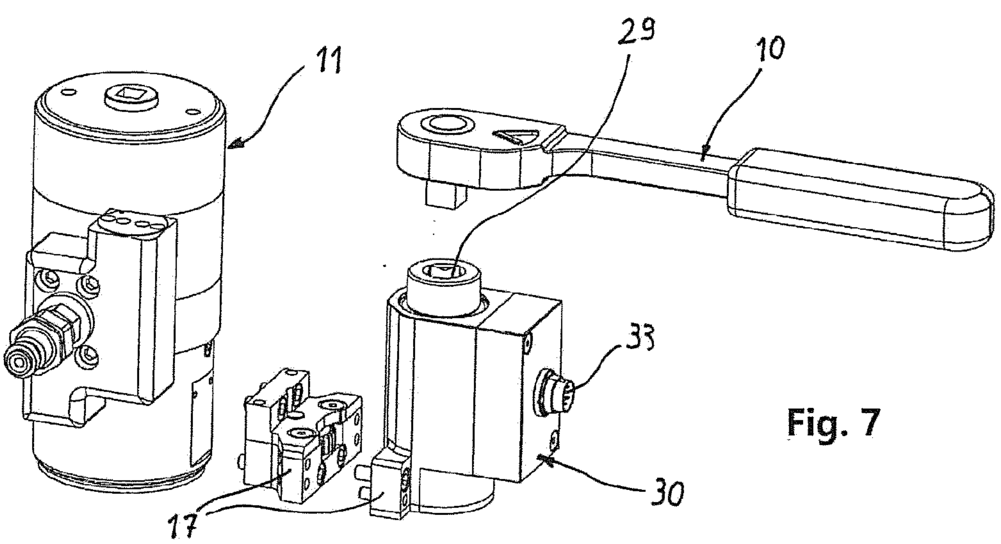

Fig. 7