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Description

The invention relates to a screw nut and an assembly device.

As described in DE 10 2009 038 211 A1, a device for determining and/or monitoring a prestressing force of a screw connection is known from the prior art. The device comprises a sensor for determining and/or monitoring the prestressing force of the screw connection, said sensor generating data that is dependent on the value of the prestressing force and/or on a change in the prestressing force, the device further comprising a transmitter unit for transmitting the data from the sensor, and an energy source that supplies the sensor and/or the transmitter unit with electrical energy.

In WO 2017/203220 A1, a method and a device for measuring a resonant frequency of an object and for monitoring a tensile load in a screw are described. A smart nut and bolt assembly comprises a nut, a bolt that is attachable to the nut, and a cap that is releasably mountable to the nut. The cap includes sensor means for sensing the tensile load on the nut and bolt assembly as a measure of the strength of the nut on the bolt. The cap also includes a transmitter for transmitting the tensile load sensed on the nut and bolt assembly to a remote location to monitor changes in the tensile load.

From US 2010/0054891 A1, a fastening device comprising a bolt or a nut and a detection system of the fastening device that detects an axial force of the fastening device are known. The detection system comprises an axial force detector having a strain gauge and an IC tag, wherein the strain gauge is provided at a predetermined position to detect an axial force value of the fastener, and the IC tag is connected to the strain gauge and wirelessly transmits the detected axial force value and unique identification information. The axial force detector is supplied with power. A reader reads the data transmitted by the axial force detector.

US 2007/0204699 A1 describes a strain measurement in a remote mechanical device. A sensor arrangement measures in the mechanical device and transmits an indication of the measurement to a remote device via a wireless connection.

DE 10 2005 015 688 A1 describes a device and a method for recording data relating to the prestressing force of connection elements and for recording marking data of connection elements. The device comprises an ultrasonic thin-film technology sensor for measuring the prestressing force in a connection element, said sensor being designed as a firmly adhering part of the fastener, a data carrier, which is also designed as a firmly adhering part of the connection element and which contains marking data for identifying the connection element, and a means for assigning the measured prestressing force to the marking data of a specific connection element.

In US 2013/0186951 A1 a smart fastening element is described. The smart fastening element has a head and a shank with an external thread for threaded engagement with a structural element. The head has a recess formed in the upper surface for attaching an RFID tag. The RFID tag comprises a memory containing specific fastening element information, an antenna to enable bi-directional communication with an RFID tag reader, and a torque value sensor to determine the torque applied to the fastening element by a fastening element installation tool. After installation, the torque present on a plurality of fastening elements is measured by using an RFID tag reader to scan the information stored in the memory of each fastening element.

The object of the invention is to provide a screw nut that is improved compared to the prior art and an assembly device that is improved compared to the prior art.

The object is achieved according to the invention by a screw nut having the features of claim 1 and an assembly device having the features of claim 11.

Advantageous embodiments of the invention are the subject of the dependent claims.

A screw nut according to the invention comprises a sensor module for determining a prestressing force of a screw connection produced or to be produced by means of the screw nut, wherein the sensor module comprises at least one deformation-detecting sensor, which is arranged on a main body of the screw nut, for detecting a deformation of the main body of the screw nut and comprises an RFID transponder unit, and wherein a printed circuit board of the sensor module is arranged on an end side of the main body, for example is arranged directly thereon or is arranged, for example, on a layer arranged between the printed circuit board and the end side, for example resting on the end side. The printed circuit board is attached, in particular mounted, to this end side of the main body. In particular, an antenna of the RFID transponder unit and an electronic circuit of the sensor module are formed on the printed circuit board. Advantageously, the entire RFID transponder unit is arranged on the printed circuit board. The printed circuit board is electrically conductively coupled to the at least one deformation-detecting sensor.

The screw nut according to the invention is a telemetric screw nut which, in particular due to the RFID technology, enables a contactless determination of the prestressing force of the screw connection produced or to be produced by means of the screw nut, since the data transmission between the sensor module, in particular its RFID transponder unit, and an RFID reader unit takes place wirelessly via an electromagnetic field and thus by means of radio transmission. Furthermore, it is not necessary for the screw nut to have an electrical energy source to operate the sensor module, as the RFID technology also transfers electrical energy from the RFID reader unit to the sensor module by means of the electromagnetic field. However, the sensor module, in particular the RFID transponder unit, can, for example, have a rechargeable electrical energy store, in particular a capacitor, for storing, at least for short-term intermediate storage, the electrical energy transmitted by the RFID reading unit, as will be explained below.

According to the invention, the printed circuit board is of annular design, in particular, at least substantially, of circular or elliptical design or is designed with a hexagonal outer contour. A clear width of a passage opening in the printed circuit board and, expediently, also of the entire sensor module is at least as large as a clear width of a screw opening in the main body of the screw nut in order to enable the screw nut to be screwed onto a screw or a threaded bolt or a threaded rod. In the case of a round passage opening, the diameter of the passage opening is therefore at least as large as the diameter of the screw opening. Advantageously, the clear width of the passage opening and, in the case of a round passage opening, its diameter is larger than the clear width or the diameter of the screw opening.

The at least one deformation-detecting sensor is advantageously arranged in the region of an outer circumferential side of the main body. For example, it is arranged on a side face, i.e. on a tool engagement surface section, or it is arranged, for example, in a cavity which is formed in a side face, or it is arranged, for example, in an axial bore in the region of an edge between two adjoining side faces. A main body of the screw nut designed as a hexagon nut has six such side faces and six edges, wherein each edge is formed between two adjacent side faces. A main body designed as a square nut correspondingly has four such side faces and four edges.

Advantageously, all components of the sensor module, for example with the exception of the at least one deformation-detecting sensor or the plurality of deformation-detecting sensors and/or one or more further sensors and electrical connecting lines between the printed circuit board and the at least one or the respective deformation-detecting sensor and/or between the printed circuit board and the respective further sensor, are arranged, in particular mounted, in particular fastened, on the annular printed circuit board and thus together with the printed circuit board on the end side of the main body, in particular on the end side, and the entire sensor module has the passage opening, wherein the arrangement on the main body is designed in such a way that the screw, the threaded bolt or the threaded rod can be fed through the sensor module. If the sensor module has a protective sleeve, this advantageously applies to the sensor module including the protective sleeve.

The at least one deformation-detecting sensor is advantageously designed as a sensor for detecting strains, compressions and/or shear forces, in particular as a strain sensor, in particular as a strain gauge sensor.

As already mentioned above, in one possible embodiment the sensor module, in particular its RFID transponder unit, can have an energy store, in particular a capacitor, which enables at least short-term storage of electrical energy transferred to the RFID transponder unit by means of an RFID reader unit, in order to be able to determine the prestressing force by means of the sensor module, for example, even if no energy is transferred to the RFID transponder unit by means of the RFID reader.

The antenna is advantageously arranged or designed as a coil on the printed circuit board. For example, it is formed as a printed coil on the printed circuit board or is arranged as a wound coil on the printed circuit board. The antenna is thus advantageously designed as a coil which is, for example, printed on the printed circuit board or wound and arranged on the printed circuit board. The coil has a plurality of coil windings here in particular, but can also have only one coil winding in one possible embodiment. Advantageously, the antenna extends over the entire circumference of the printed circuit board. This makes it possible to read the sensor module using the RFID reader at all circumferential positions of the screw nut.

In one possible embodiment, the sensor module comprises a plurality of deformation-detecting sensors, for example two or more than two deformation-detecting sensors. Advantageously, these deformation-detecting sensors are then arranged uniformly distributed about an outer circumference on the main body of the screw nut.

Advantageously, the screw nut comprises a protective sleeve for the sensor module.

An assembly device according to the invention comprises such a screw nut and a spanner.

For example, the assembly device comprises an RFID reader which is fixedly connected to the spanner or is releasably connectable or connected to the spanner.

Advantageously, a screw nut receptacle of the spanner is designed to correspond to the screw nut. For example, the screw nut receptacle of the spanner has at least one recess for receiving the at least one deformation-detecting sensor of the screw nut. This at least one recess is advantageously designed in a manner corresponding to a region of the at least one deformation-detecting sensor projecting beyond a surface of the main body of the screw nut.

In particular, the screw nut enables strain measurement on the screw nut, i.e. on its main body. For this purpose, the at least one deformation-detecting sensor, in particular a strain gauge sensor, is advantageously arranged together with an analogue-digital converter unit and the RFID transponder unit, which enables contactless electromagnetic coupling of the sensor module, in particular by means of an RFID reader, for energy and data transmission, arranged on the main body of the screw nut, wherein the printed circuit board, which simultaneously realizes the circuit, antenna and sensor contacting and is expediently designed in such a way that a spanner can also be used and the screw or threaded bolt can advantageously be passed through it, is arranged on the end side of the screw nut, i.e. in particular on an end side of the screw nut. i.e. in particular on an end side of the main body.

The deformation, in particular the strain (or compression, since this is a negative strain), is advantageously detected by means of the at least one deformation-detecting sensor on the outer circumferential side of the main body of the screw nut or at least in the region of the outer circumferential side, for which purpose the at least one deformation-detecting sensor is arranged accordingly, as described above. In particular, a deformation, in particular strain and/or compression, i.e. negative strain, is detected in the axial direction of the screw nut, i.e. in the screwing direction of the screw nut and thus of the screw connection produced or to be produced. Advantageously, the sensor module comprises, as described above, a plurality of such deformation-detecting sensors, so that a corresponding deformation detection at a plurality of measuring points on the main body of the screw nut is made possible. In an advantageous embodiment, the at least one or the respective deformation-detecting sensor, as already mentioned above, is arranged in a cavity formed in the main body of the screw nut. As a result, the deformation-detecting sensor is advantageously flush with an adjacent outer surface of the main body.

The solution according to the invention enables in particular a fast, simple, reliable and cost-effective determination of the prestressing force in screw connections. Advantageously, for this solution according to the invention, minimal or no mechanical changes need to be made to the components used for the screw connection, for example to a screw, washer and advantageously also to the main body of the screw nut. As a result, existing standards and approvals for these components continue to be complied with. In the solution described above, this is advantageously the case at least for those embodiments of the screw nut in which no cavity or axial bore is formed in the main body of the screw nut for the at least one or the respective deformation-detecting sensor, because in these embodiments all components of the sensor module are attached to the surface of the main body. The main body of the screw nut advantageously corresponds to the conventional, for example standardized and/or approved, screw nut. Advantageously, no mechanical changes are made to this main body, but the sensor module is merely attached to this main body, i.e. to the conventional screw nut.

The measurement, i.e. the deformation detection on the main body of the screw nut, is advantageously carried out, as already mentioned above, by means of a deformation-detecting sensor designed, for example, as a strain or force sensor and without electrical contacting on the screw nut, i.e. by means of wireless data transmission and in particular also by means of wireless electrical energy transmission between the screw nut, in particular its sensor module, and the RFID reader. Attaching the sensor module to the main body of the screw nut considerably simplifies the taking of such measurements, as screw nuts are standardized and easily interchangeable and have much less variety than screws, for example.

In order to avoid possible influences on the strength of the screw connection, the overall size of the sensor module is advantageously miniaturized, at least to the greatest possible extent. The design of the at least one or the respective deformation-detecting sensor as a strain gauge sensor, also referred to as a strain gauge sensor for short, is very advantageous for this purpose. As already described above, the strain (also negative strain, i.e. compression) of the main body of the screw nut is advantageously detected by means of the at least one deformation-detecting sensor, in particular strain gauge sensor, on one side face or, in the case of a plurality of such deformation-detecting sensors, on a plurality of side faces of the main body of the screw nut, which is correlated with a prestressing force applied in the screw connection.

As already described, RFID technology for energy and data transmission is advantageously used to realize the contactless detection of the strain. This means that no additional electrical energy source, in particular no battery, is required for the electrical energy supply, so that the entire sensor module can be attached to the main body of the screw nut in a miniaturized and robust design and can be used very flexibly together with it as one component in a respective application.

For example, a standard mobile RFID reader can be used to read out the prestressing force applied in the screw connection. The advantageous design of the sensor module, in particular the antenna, which advantageously extends over the entire circumference of the annular printed circuit board according to the invention, enables direction-independent and thus fast, ergonomic and safe reading of measured values that have been determined and in particular already digitized in the sensor module, regardless of the angle of rotation of the screw nut.

The screw nut described herein, in particular with the sensor module described herein, thus enables reliable and ergonomic measurement of the prestressing force both during installation of the screw connection and, for example, during subsequent cyclical inspections during an entire life cycle of the screw connection, in particular due to the fact that the sensor module operates passively, i.e. does not require a battery and is supplied with electrical energy via the external RFID reader.

The solution described here has considerable advantages over other possible solutions for determining the prestressing force of a screw connection. The prestressing force is the quality-determining parameter for every screw connection, so that its measurement is required for many applications. Measuring a torque using a torque spanner represents the prior art technology used in daily practice today. However, the measured values obtained using this method are heavily dependent on the existing friction conditions, so that there is not always a clear correlation between the measured torque and the prestressing force applied in the screw connection. The solution described here avoids such measurement inaccuracies, as the values of the prestressing force determined in this way are independent of friction ratios, because the solution described here advantageously determines the deformation, in particular in the axial direction of the main body of the screw nut, in particular a strain and/or compression, i.e. negative strain.

In the solution described here, the prestressing force applied in the screw connection is advantageously determined on at least one side face or, in the case of a plurality of deformation-detecting sensors, correspondingly on a plurality of side faces of the main body of the screw nut by means of one or more deformation-detecting sensors designed in particular as strain sensors.

The main body of the screw nut is advantageously made of metal, since the measurement of the prestressing force is particularly important for screw connections with screw nuts made of metal. However, the solution described is also suitable for screw nuts of which the main body is made of a different material, for example plastic or ceramic.

When the screw connection is tightened, mechanical stresses are built up in the main body of the screw nut and are directly correlated with the applied prestressing force and can be registered on the respective side face of the main body as a strain (or compression as negative strain).

For reasons of symmetry, the corresponding deformation-detecting sensor is advantageously positioned centrally or as centrally as possible on the side face of the main body of the screw nut. Since, under real operating conditions, the screw connection is usually not tightened in exactly the same way due to unevenness on the components involved, an angled assembly and/or impurities and thus does not lead to a rotationally symmetrical distribution of the forces, at least two deformation-detecting sensors, in particular designed as strain gauge sensors, are advantageously provided to increase the measuring accuracy and are arranged, for example, on two opposing side faces of the main body of the screw nut or are arranged in a respective cavity in the respective side face or are arranged in opposing axial bores. Advantageously, a calculation and/or evaluation of the respective measured values of these deformation-detecting sensors is then provided, for example by means of a suitable evaluation algorithm, for example by simple addition or formation of an average value.

Advantageously, all sensor types commonly used for mounting on metal can be used as a deformation-detecting sensor, in particular a strain gauge sensor, for measuring strain, compression and shear forces, in particular if the main body of the screw nut is made of metal. For example, the at least one or the respective deformation-detecting sensor is designed as a metal strain gauge resistor on foil, as a semiconductor strain gauge resistor or as a piezoresistive strain gauge.

Mounting of the deformation-detecting sensor on the side face of the main body of the screw nut or mounting of the respective deformation-detecting sensor on the respective side face of the main body of the screw nut is advantageously carried out by adhesive bonding, for example with an acrylate or with an epoxy resin, by spot welding or vitrification.

In one possible embodiment, the deformation-detecting sensor or the respective deformation-detecting sensor, in particular a strain gauge sensor, is designed as a single sensor element which is mounted in such a way that a force is measured in the axial direction of the screw nut, i.e. in the direction of its longitudinal axis, in particular its axis of rotation, about which it is rotated to produce the screw connection.

However, strain gauge sensors usually have a very low impedance (<=1 kΩ) and only provide a very small measurement signal (<1 mV), which is often also temperature-dependent. For this reason, in an advantageous embodiment, the individual sensor element in the deformation-detecting sensor or in the respective deformation-detecting sensor is operated together with at least one reference fixed resistor as a half bridge or as a full bridge.

In a further possible embodiment, it is provided that the plurality of deformation-detecting sensors of the screw nut, each designed as a strain gauge sensor, in particular as a single sensor element, are interconnected to form a measuring bridge. This can simplify the evaluation of the recorded measured values.

In a further possible embodiment, the at least one or the respective deformation-detecting sensor, in particular strain gauge sensor, has a plurality of sensor elements which are connected in the form of a half bridge or full bridge and/or have temperature compensation. This is particularly advantageous for screw nuts, especially main bodies, with a large size.

In a possible further embodiment, the at least one or the respective deformation-detecting sensor is designed, for example, as a more complex strain gauge sensor, in particular as a so-called rosette strain gauge. However, this requires multi-channel measurement electronics.

As already described above, the measured values recorded by means of the at least one deformation-detecting sensor or the measured values recorded by means of the plurality of deformation-detecting sensors are read out using RFID technology, i.e. by means of an RFID reader and by means of the RFID transponder unit of the sensor module, in particular contactlessly and wirelessly and without using a battery in the sensor module. The RFID reader and the RFID transponder unit operate in the HF or UHF range, for example. The sensor module is powered by the electromagnetic field emitted by the RFID reader. Bidirectional data transmission between the RFID reader and the sensor module, in particular its RFID transponder unit, also takes place via the same electromagnetic field, as is usual with RFID technology.

The sensor module, in particular its RFID transponder unit, advantageously comprises a so-called power management, i.e. an energy management unit. It includes, for example, voltage stabilization, filtering, voltage monitoring and optionally the aforementioned energy store, in particular in the form of a capacitor, which ensures the electrical power supply for a predetermined minimum time when the electromagnetic field of the RFID reader is switched off, for example in order to improve a signal-to-noise ratio by switching it off, so that it is also possible to determine the bias force in this case.

An analogue-to-digital converter is advantageously provided for measuring the voltage of the at least one deformation-detecting sensor, in particular in the form of a strain gauge sensor, or of the multiple deformation-detecting sensors, which, in particular in the case of multiple deformation-detecting sensors, advantageously has multiple signal inputs. Alternatively, a separate analogue-to-digital converter can also be provided for each deformation-detecting sensor, wherein in this case the analogue-to-digital converters are advantageously positioned as close as possible to the respective deformation-detecting sensor in order to improve interference immunity.

The printed circuit board of the sensor module is advantageously designed as already mentioned above. It advantageously has an at least approximately circular or elliptical contour or a contour comprising a hexagonal outer contour. Advantageously, all electronic components of the sensor module, with the exception of the at least one or the respective deformation-detecting sensor, are arranged on the printed circuit board. One material of the printed circuit board is, for example, FR4 or a similar material. The printed circuit board comprises a plurality of layers, for example two to six layers. A thickness of the printed circuit board is, for example, approximately 1.0 mm. Alternatively, a polymer film can be used for the printed circuit board, for example. The printed circuit board is advantageously arranged on the end side of the main body of the screw nut that is opposite the application of force. It is advantageously fixedly connected to the main body of the screw nut. It is advantageously positioned coaxially with the main body of the screw nut. The arrangement of the printed circuit board on the side opposite the application of force means, in particular, that the screw nut described here is intended to be arranged in the screw connection in such a way that the printed circuit board is positioned on the side opposite the application of force. This prevents the sensor module from being destroyed by the force of the screw connection.

The size of the passage opening in the annular printed circuit board is, as already mentioned above, suitably dimensioned so that the screw or threaded rod used for the screw connection or the threaded bolt can be securely inserted through this passage opening.

Due to the required installation space for the printed circuit board, the solution described is particularly suitable for screw nuts, i.e. for main bodies of screw nuts, larger than or equal to M10. To miniaturize the size and increase robustness, all components on the PCB are advantageously mounted on one side using SMD (surface-mounted-device) and/or flip-chip mounting and/or COB mounting (chip-on-board technology). The position of the electronic components on the annular PCB can be selected relatively freely. This position of the electronic components on the printed circuit board is therefore advantageously optimized in terms of interference immunity and/or manufacturing costs.

In addition, this annular printed circuit board serves as a carrier for the antenna for electromagnetic coupling with the RFID reader. The antenna is advantageously designed on the printed circuit board as a coil, in particular as a printed antenna. The number of turns of this coil, i.e. the antenna, is substantially dependent on the RFID carrier frequency used and the size of the main body of the screw nut. In particular, the number of turns is determined by the inductance required for resonance. For example, a number of turns of 2 to 20 is appropriate for high-frequency transponders. For example, the number of turns is ten turns or approximately ten turns.

Furthermore, the printed circuit board is used for the electrical contacting of the at least one or the respective deformation-detecting sensor, which is advantageously arranged on the side face of the main body of the screw nut, in particular in the form of a strain gauge sensor, for example by means of soldering, adhesive bonding or wire bonding. Electrical conductor tracks between the at least one deformation-detecting sensor or the plurality of deformation-detecting sensors and the analogue-to-digital converter or the multiple analogue-to-digital converters are advantageously designed to be as short as possible to improve interference immunity, run advantageously in parallel, and are advantageously shielded by copper surfaces located above and below in the printed circuit board. The described multiple function of the printed circuit board leads to a considerable reduction in the size and cost of the sensor module and thus of the screw nut described here.

The screw nut described here is thus designed as a measuring nut, which advantageously consists of the main body, which forms the actual, advantageously conventional, screw nut, and of the sensor module. The sensor module advantageously consists of the at least one deformation-detecting sensor, advantageously designed as a strain gauge sensor, or a plurality of such deformation-detecting sensors, in particular mounted on a side face or in each case a side face of the main body of the screw nut, the printed circuit board and, advantageously, a protective sheath, i.e. the protective sleeve, in order to ensure that the deformation-detecting sensor can be used as a sensor module. i.e. the protective sleeve, around the sensor module, in particular around the at least one deformation-detecting sensor or around the plurality of deformation-detecting sensors and around the printed circuit board, in particular also around the components arranged thereon. The entire structure of the screw nut described here is advantageously designed in a monolithic construction in order to obtain a robust, flexible and contactless measuring device for the application of the prestress measurement in screw connections.

The screw nut described herein is advantageously suitable as an object for tightening screw connections like a standard screw nut without fundamental losses in stability, since, at least in some advantageous embodiments, an original screw nut is advantageously used as the main body without changes to its structure, advantageously at least in the embodiments that do not have a cavity or axial bore for the respective deformation-detecting sensor.

The described embodiment as an annular printed circuit board with a printed annular antenna which encloses the screw opening of the main body of the screw nut and, if the screw nut is screwed onto the screw or threaded rod or the threaded bolt, also this screw or threaded rod or the threaded bolt, if the latter projects through the screw opening, leads to an at least approximately rotationally symmetrical structure, in particular with respect to the antenna, so that the sensor module and thus the screw nut described here, which forms the measuring nut, can be read out without contact and independent of direction. This avoids readability from only one preferred direction. This property is of particular importance for the application of the screw nut for measuring the prestressing force, as it is not possible to predict at which angle of rotation the required prestressing force will be achieved when tightening the screw connection and at which angle the measured sensor values can therefore be read out. This independence of direction therefore makes it considerably easier to use the screw nut described here to measure the prestressing force.

To tighten the screw connection, in particular the screw nut, open-end spanners, ring spanners or similar tools are usually used, which must be brought into contact with the screw nut for this purpose and cause a considerable force effect on the screw nut for tightening. In order to further enable a practicable and safe use of these tools, the at least one or the respective deformation-detecting sensor is therefore mounted on the main body at a suitable position and with the lowest possible overall height, and advantageously the protective sheath, i.e. the protective sleeve, is provided for its protection, for example in the form of a potting layer or a housing, so that the at least one or the respective deformation-detecting sensor is protected from possible loads or damage by these tools.

As already described, the assembly device comprising the screw nut and the spanner or another suitable tool may provide that the shape of the tool to be used, in particular the spanner, is modified in a suitable manner in order to ensure easy handling and avoid possible damage. This modification can, for example, consist of one or more bulges in the rear jaws of the spanner. The screw nut receptacle of the spanner thus advantageously has at least one recess for receiving the at least one deformation-detecting sensor of the nut, wherein this at least one recess is designed to correspond to the region of the at least one deformation-detecting sensor projecting beyond the surface of the main body of the nut. This makes it possible, for example, to use an open-end spanner safely even with two deformation-detecting sensors mounted opposite each other on the main body.

Advantageously, the printed circuit board including the protective sleeve, for example in the form of a housing or a protective sheath, for example in the form of a moulding, does not protrude beyond a contour of the main body, in the case of a hexagonal nut beyond the hexagonal contour, in the region of the at least one or the respective deformation-detecting sensor at least no further than this deformation-detecting sensor or the respective deformation-detecting sensor beyond the contour. This also prevents possible damage caused by a spanner being used.

The overall height of the circuit board, in particular the sheathed circuit board, is as low as possible, for example in the range of a few millimetres, for example in the range of 1 mm to 10 mm. The design described achieves good overall protection of the sensor module including the at least one deformation-detecting sensor, in particular designed as a strain gauge sensor, or the respective such deformation-detecting sensor against damage during handling, in particular during tightening or loosening of the screw nut, with the spanner.

Advantageously, the assembly of the screw nut described here therefore does not differ significantly in terms of the tools to be used and the effort involved compared to the assembly of a comparable conventional screw nut without a sensor module. Assembly is thus still very simple, reliable and inexpensive, for example using a spanner.

As already mentioned, in a possible embodiment, it may be provided that the at least one deformation-detecting sensor is arranged in a cavity which is formed in a side face of the main body, or the respective deformation-detecting sensor is arranged in a respective cavity which is formed in a respective side face of the main body. The cavity or the respective cavity is thus a recess in the side face of the main body of the screw nut. This further improves the protection of the at least one or the respective deformation-detecting sensor.

The cavity or the respective cavity is advantageously formed here up to the printed circuit board in order to also protect supply lines to the deformation-detecting sensor or to the respective deformation-detecting sensor, i.e. connecting lines between the printed circuit board and the at least one or the respective deformation-detecting sensor.

The cavity or the respective cavity is advantageously formed, in particular formed so deeply into the main body, such that the at least one or the respective deformation-detecting sensor, including the supply lines, is installed flush in the side face or in the respective side face of the main body of the screw nut. This means that damage caused by the spanner can be ruled out or at least virtually ruled out, for example even if a normal spanner is used that does not have a special recess to accommodate the at least one or the respective deformation-detecting sensor.

As already mentioned, in one possible embodiment of the assembly device it is provided that an RFID reader is fixedly connected to the spanner or is releasably connectable or connected to the spanner. This makes it possible to constantly determine and display the prestressing force even while the screw nut is being tightened. The RFID reader has, for example, a display unit, in particular a display, to show the measured value of the determined prestressing force. Alternatively or additionally, it may be possible, for example, for the measured values determined for the prestressing force to be transmitted via a cable or wirelessly, for example via Bluetooth or other wireless communication technologies, to another device, for example a mobile phone, in particular a smartphone, and/or to a portable computer, in particular a tablet or notebook, and displayed and/or stored there. In this case, the RFID reader has a corresponding wired or wireless data transmission interface. Alternatively or additionally, for example, the RFID reader can also have a memory for storing the determined measured values of the prestressing force.

A significant advantage of determining the prestressing force of the screw connection on the screw nut, which is made possible with the screw nut described here, is that the conventional screw nut and thus also the main body of the screw nut described here is advantageously a cost-effective component, which is offered in standardized sizes and designs, and that product variability is significantly lower compared to screws. This means, for example, that conventional screw nuts can be used as the main body for the screw nut described here, which is designed as a sensor nut, which is then fitted with the sensor module, in particular with one or more deformation-detecting sensors, in particular in the form of strain gauge sensors, in accordance with the structure described here. This enables cost-effective production in larger series, especially in comparison to screws or even special screws.

Compared to other possible solutions, the determination of the prestressing force acting in a screw connection with a screw nut provided with the sensor module described here permits effective mass production, warehousing and marketing of this screw nut designed as a sensor nut, in particular with regard to standardized screw nuts.

In addition, it is much easier to replace the screw nut, for example in the event of a failure and/or to recalibrate the at least one or the respective deformation-detecting sensor, than to replace other components of the screw connection, for example the screw or the threaded bolt, from which the arrangement of such sensors would also be conceivable.

In one possible embodiment, it is envisaged that the sensor module has one or more further sensors in addition to the at least one deformation-detecting sensor or the plurality of deformation-detecting sensors, in particular in the form of a strain gauge sensor. This further sensor or the plurality of further sensors is/are then also operated and read out as part of the sensor module using RFID technology, analogously to the at least one or the respective deformation-detecting sensor.

For example, one or more temperature sensors are arranged on the printed circuit board of the sensor module and/or in the region, in particular in the immediate vicinity, of the at least one or the respective deformation-detecting sensor. A temperature determined with this temperature sensor or with the respective temperature sensor can then be used, for example, for temperature compensation of the signals measured with the at least one or the respective deformation-detecting sensor.

Alternatively or additionally, the sensor module can, for example, have one or more three-dimensional acceleration sensors, in particular on a MEMS basis. The at least one or the respective acceleration sensor is advantageously arranged on the printed circuit board, in particular on the FR4 printed circuit board, and can in particular detect even slight changes in position of the sensor module and thus of the measurement object, in particular the screw nut. This information can be particularly relevant for movable measurement objects, such as screw nuts. Alternatively or additionally, such sensors, in particular MEMS sensors, also allow accelerations and/or vibrations to be determined, for example. Alternatively or additionally, such a sensor, in particular a MEMS sensor, can also be provided with at least one additional sensor for determining an angular velocity and/or magnetic field strength, in particular also the earth's magnetic field.

Since larger metal surfaces in the immediate vicinity of a coil generally lead to an influence on this coil with regard to its inductance and its quality, this also applies to the antenna, which is advantageously designed as a coil, in particular a printed coil, on the printed circuit board of the sensor module. As this antenna is intended and used for coupling with the RFID reader, it forms a parallel resonant circuit together with a capacitor. If the screw or threaded bolt and, for example, a washer used are made of metal, the resonant frequency of the resonant circuit is detuned by this metal, in particular due to eddy current losses occurring in it and any permeable materials used, for example steel, and the quality of the resonant circuit is significantly reduced. This leads to a negative influence on the energy and data transmission via the RFID coupling of the sensor module, in particular the RFID transponder unit, with the RFID reader. The resulting detuning of the resonant frequency can be corrected by means of a corresponding adjustment. To avoid an excessive reduction in the quality of the resonant circuit due to the metal and thus the maximum possible reading distance for the RFID reader, a predetermined minimum distance between the coil forming the antenna on the printed circuit board and the main body of the screw nut and its internal thread is advantageously provided. This minimum distance is 1 mm, for example. In other words, the antenna of the sensor module, in particular the RFID transponder unit, advantageously has a minimum distance of 1 mm from the main body and/or its screw opening, in particular from the thread in the screw opening. The antenna is thus designed and arranged accordingly. In particular, the antenna is formed and arranged accordingly on the printed circuit board and the printed circuit board is arranged accordingly on the main body to ensure this.

The antenna on the printed circuit board of the sensor module, in particular the antenna designed as a coil, in particular its design, is thus advantageously formed in such a way that the windings of the coil on the annular printed circuit board are advantageously located as far outwards as possible and are advantageously preferably arranged on a layer of the printed circuit board, also referred to as a layer, which is located furthest away from the main body, i.e. has the greatest distance from the main body. The windings can also be arranged on a layer positioned, for example, next below the layer furthest away, for example if coils with many windings are used. It is also possible for windings to be arranged on a plurality of layers of the printed circuit board.

In one possible embodiment, for example, it may be provided that the distance between the printed circuit board and the main body of the screw nut, which is formed in particular from metal, is increased by a non-electrically conductive layer located between them. In other words, in this embodiment, such a non-electrically conductive, in particular electrically insulating, layer is arranged between the printed circuit board and the main body. Alternatively, this layer between the printed circuit board and the main body of the screw nut is made of a permeable material, for example, which can effectively reduce the eddy currents induced in the metal by distorting the field lines. The permeable material used for this layer is advantageously selected in such a way that it does not exhibit excessive losses even at a frequency of 13.56 MHz (the preferred frequency used by the RFID transponder unit and the RFID reader). This material can be produced, for example, by mixing a suitable ferrite powder into a flexible plastic.

The use of RFID technology offers significant further advantages in addition to the realization of the determination function described, in particular with regard to the prestressing force.

In particular, the use of a non-volatile data memory of the RFID transponder unit for storing information such as identification number, calibration data of the sensors of the sensor module, manufacturer and type information of the screw nut designed as a sensor nut and/or utilization data is very advantageous. Thanks to the anti-collision algorithms that are usually implemented, RFID technology also offers the option of parallel measurement and reading of a plurality of screw nuts designed as sensor nuts in the manner described above, which are located on the same side in the electromagnetic field of the RFID reader. If the special NFC (Near Field Communication) version is used as RFID technology, the measurement data determined can also be read out using a mobile phone, in particular a smartphone with an NFC interface or other devices with an NFC interface, for example, and can be displayed and processed particularly easily when transmitted, for example as an NDEF message. In one possible embodiment, the RFID transponder unit of the sensor module is thus designed as an NFC transponder unit and the RFID reader is designed as an NFC reader, for example as a mobile phone, in particular a smartphone, or as a portable computer, for example a tablet or notebook, with an NFC interface.

In one possible embodiment, for example, it may be provided that the main body of the nut is longer, i.e. larger, in the axial direction than a comparable standardized screw nut. This improves the measuring accuracy with regard to the prestressing force. In the case of standardized conventional hexagon nuts, their height, i.e. their size in the axial direction, is usually approximately half the width across flats. The width across flats refers to the spanner intended for use with the nut. In the embodiment described here, the main body is thus advantageously larger in the axial direction, i.e. with respect to its height, i.e. larger than half the spanner width, in particular significantly larger. For example, this height of the main body corresponds to at least two thirds or three quarters or four fifths of the spanner width or at least the spanner width.

In one possible embodiment, provision may be made for additional labelling of the associated screw/threaded bolt and/or the screwed components of the screw connection with a transponder and/or with a matrix or barcode in order to identify the measuring point at which the screw nut is located. This avoids, for example, that there is no assignment to the location of the measurement of the prestressing force when the screw nut is replaced. The measured values determined by the screw nut, which is designed as a sensor nut, are advantageously stored linked to an ID number of the screw nut, which is advantageously stored in its RFID transponder unit. If the above-described labelling of the measuring point is provided, it is thus possible to additionally link these measured values with this labelling of the measuring point, i.e. with corresponding identification information of the measuring point, and to store this together. This makes it possible to clearly assign the determined measured values, in particular with regard to the prestressing force, to the nut and the measuring point.

As already mentioned above, in one possible embodiment it may be provided that the at least one or the respective deformation-detecting sensor is arranged in an axial bore in the region of an edge between two adjacent side faces in the main body. This is another way of arranging the at least one or the respective deformation-detecting sensor, in particular in a protected manner. Furthermore, this enables a particularly good coupling with the main body for detecting its deformation corresponding to the prestressing force.

In one possible embodiment, it may be provided that the entire sensor module, i.e. including the printed circuit board with antenna and RFID transponder unit and of course including the at least one deformation-detecting sensor, is arranged on a side face of the main body of the screw nut. Although this enables measurement and, in particular, reading by means of the RFID reader at only one point, the determination of the prestressing force is therefore less accurate and the lateral height of the screw nut in the region of the sensor module is greater, this design is particularly cost-effective. In particular due to the greater lateral height, i.e. the greater extent in the radial direction of the screw nut in the region of the sensor module, this embodiment is advantageously suitable for larger main bodies, for example from dimension M18.

As an alternative to the screw nut described above, it can also be provided, for example, that the sensor module described above and used there for the screw nut is arranged on a screw head of a screw. A sensor screw is thus formed, comprising a screw main body and the sensor module. The at least one or the respective deformation-detecting sensor is then arranged on the screw head, in particular at a suitable location and with suitable alignment, or on a side face of the screw head, in the same way as with the screw nut described above. Alternatively, the deformation-detecting sensor can, for example, be arranged rotationally symmetrically on the screw head, wherein this deformation-detecting sensor then advantageously integrates asymmetrically applied forces due to its structure. This means that only one deformation-detecting sensor, in particular a strain gauge sensor, is required.

Exemplary embodiments of the invention are explained in greater detail below with reference to drawings, in which:

Figure 1 shows a schematic perspective view of an embodiment of a screw nut,

Figure 2 schematically shows the determination of a prestressing force of a screw connection,

Figure 3 schematically shows a sensor module,

Figure 4 schematically shows a top view of an end side of an embodiment of a screw nut,

Figure 5 schematically shows a side view of an embodiment of a screw nut with a sensor module, shown in section, of the screw nut,

Figure 6 schematically shows a detail of a longitudinal sectional view of an embodiment of a screw nut,

Figure 7 schematically shows a detail of a longitudinal sectional view of a further embodiment of a screw nut,

Figure 8 schematically shows an assembly device,

Figure 9 schematically shows a detail of a side view of an embodiment of a screw nut, and

Figure 10 schematically shows a detail of a longitudinal sectional view of the screw nut embodiment according to Figure 9.

Corresponding parts are provided with the same reference signs in all figures.

With reference to Figures 1 to 10, a screw nut 1 and an assembly device 2 comprising such a screw nut 1 and a spanner 3 are described below. A screw connection can be produced with the screw nut 1 by screwing this screw nut 1, in particular by means of the spanner 3, for example onto a screw 4, onto a threaded rod or onto a threaded bolt.

In all the embodiments shown, the screw nut 1 comprises a sensor module 5 for determining a prestressing force of the screw connection. The screw nut 1 described here is thus designed as a sensor nut, which comprises a main body 6 as the actual nut and additionally the sensor module 5, which is arranged on this main body 6.

The sensor module 5 comprises at least one deformation-detecting sensor 7 arranged on the main body 6 of the screw nut 1 for detecting a deformation of the main body 6 of the screw nut 1 or a plurality of such deformation-detecting sensors 7, in the exemplary embodiments shown here advantageously two such deformation-detecting sensors 7 in each case, and an RFID transponder unit 8. A printed circuit board 9 of the sensor module 5, on which an antenna 10 of the RFID transponder unit 8 and an electronic circuit of the sensor module 5 is formed and on which the entire RFID transponder unit 8 is advantageously arranged, and which is electrically conductively coupled to the respective deformation-detecting sensor 7, is arranged on an end side 11 of the main body 6, in particular on the end side 11, in particular on a surface of this end side 11, advantageously only on the surface of this end side 11, in particular not projecting inwards beyond this surface in the direction of a screw opening 13 of the main body 6. It can rest directly on the end side 11 or be spaced apart from it, but is advantageously always attached to the end side 11, i.e. in particular connected to the end side 11.

The screw nut 1 described here in the form of a sensor nut is thus a telemetric screw nut 1, which enables contactless measurement of the prestressing force in the screw connection produced or to be produced by means of the screw nut 1.

According to the invention, the printed circuit board 9 is of annular design, in particular of circular or elliptical design, as can be seen in particular in Figure 4. The annular printed circuit board can also have a hexagonal outer contour. According to the invention, a clear width of a passage opening 12 of the printed circuit board 9 and, expediently, also of the entire sensor module 5 is at least as large as a clear width of the screw opening 13 of the main body 6 of the screw nut 1, advantageously larger than the clear width of the screw opening 13, as shown in Figure 4. In this case, the printed circuit board 9 is of annular, round design, so that a diameter of the passage opening 12 of the printed circuit board 9 is larger than a diameter of the screw opening 13 of the main body 6 of the screw nut 1. Advantageously, the entire sensor module 5 is also designed to correspond to the printed circuit board 9, i.e. in particular is of annular and round design.

In the embodiments shown here, the respective deformation-detecting sensor 7 is arranged in the region of an outer circumferential side of the main body 6, for example on a side face 14, as shown in Figures 1 and 2 and Figures 4 to 8, or in a cavity 15, which is formed in a side face 14, as shown in Figures 9 and 10, or in an axial bore in the region of an edge between two adjacent side faces 14. In the examples shown here, the main body 6 is designed as a hexagonal screw and thus has six side faces 14 and six edges, with each edge being formed between two adjacent side faces 14.

By means of the respective deformation-detecting sensor 7, a strain and/or compression occurring in the axial direction of the main body 6 of the screw nut 1, i.e. negative strain of the main body 6 of the screw nut 1, is advantageously determined. Such strains and/or compressions correlate with the prestressing force during the production of the screw connection by screwing the screw nut 1 onto the screw 4, threaded rod or threaded bolt and when the screw connection is produced, so that the prestressing force can be determined from this strain and/or compression determined by means of the respective deformation-detecting sensor 7. The axial direction is the direction parallel to an axis of rotation of the main body 6 of the screw nut 1, in particular parallel to an axis of rotation of the screw opening 13 in the main body 6, about which the screw nut 1 is rotated to produce the screw connection and is thereby screwed onto the screw 4, threaded rod or threaded bolt. The respective deformation-detecting sensor 7 is thus advantageously designed accordingly and arranged on the main body 6 to enable this.

The deformation-detecting sensors 7 are advantageously arranged uniformly distributed about an outer circumference of the main body 6 on the main body 6 of the screw nut 1. In the case of the two deformation-detecting sensors 7 shown here, these are advantageously arranged opposite one another on the main body 6, as shown in Figures 2, 4, 5 and 8.

The respective deformation-detecting sensor 7 is expediently designed as a sensor for detecting strains, compressions, i.e. negative strains, and/or shear forces, in particular as a strain sensor, in particular as a strain gauge sensor.

It may be provided, in particular in the embodiments shown here, that the RFID transponder unit 8 has an energy store, in particular a capacitor. This makes it possible in particular to store electrical energy transmitted from an RFID reader 16 to the RFID transponder unit 8, in particular to temporarily store it for at least a short time, in order to then be able to carry out a determination of the bias force without connection to the RFID reader 16, wherein the sensor module 5 is operated with this electrical energy stored in the energy store.

The antenna 10 of the sensor module 5, in particular of the RFID transponder unit 8, is advantageously formed as a coil, in particular as a printed coil, on the printed circuit board 9, as shown in Figure 4.

Advantageously, the screw nut 1 comprises a protective sleeve 17 for the sensor module 5, as shown, for example, in Figure 5.

As already mentioned above, the assembly device 2 comprises the screw nut 1 and a spanner 3. It may be provided, for example, that the RFID reader 16 is fixedly connected to the spanner 3 or is releasably connectable or connected to the spanner 3. Alternatively or additionally, for example, it may be provided that a screw nut receptacle 18 of the spanner 3 has at least one recess 19 for receiving the at least one deformation-detecting sensor 7 of the screw nut 1 or the respective deformation-detecting sensor 7 of the screw nut 1 facing the screw nut receptacle 18, as shown in Figure 8. Advantageously, this at least one recess 19 or the respective recess 19 is designed to correspond to a region of this deformation-detecting sensor 7 projecting beyond a surface of the main body 6 of the screw nut 1, as shown in Figure 8.

In the following, possible features and advantages of this screw nut 1 are described in detail, in particular with reference to the embodiments shown in Figures 1 to 10.

The screw nut 1 forms a device or is, in particular together with the RFID reader 16 and, for example, with the spanner 3, a component of a device, wherein this device, in particular the screw nut 1, enables the implementation of a method for determining the prestressing force in a screw connection, in particular quickly, simply, reliably and inexpensively. Advantageously, minimal or no mechanical changes need to be made to the components used for the screw connection, for example to the screw 4 or the threaded bolt or the threaded rod, to a washer that may be used, and, advantageously, also to the main body 6 of the screw nut 1. As a result, existing standards and approvals for these components can advantageously continue to be complied with.

In particular to achieve this objective, the measurement is carried out, for example, by means of strain and/or force sensors and without external electrical contacting on the screw nut 1, i.e. the respective deformation-detecting sensor 7 is advantageously designed as such a strain and/or force sensor.

Attaching the sensor module 5 to the main body 6 of the screw nut 1 considerably simplifies the process of determining the prestressing force compared to attaching it to other components of the screw connection, since the main body 6 of the screw nut 1 is advantageously a component that is standardized and easily interchangeable, wherein nuts have a much smaller variety than screws, for example.

To avoid possible influences on the strength of the screw connection, the overall size of the sensor module 5 is advantageously miniaturized, at least as far as possible. Strain gauge sensors, hereinafter also referred to as strain gauge sensors, can very advantageously be used for this purpose as deformation-detecting sensors 7, which determine the strain on a side face 14 or, if a plurality of such deformation-detecting sensors 7 are used, preferably on a plurality of side faces 14 of the main body 6 of the screw nut 1, this strain being correlated with the prestressing force applied in the screw connection.

RFID technology for energy and data transmission is used in a particularly advantageous way to realize the contactless determination of this strain and thus the prestressing force. This means that no additional battery is required for the electrical power supply of the sensor module 5, so that the entire sensor module 5 can be attached to the main body 6 of the screw nut 1 in a miniaturized and robust design and can be used very flexibly together with this as a single component in the respective application. For example, a standard mobile RFID reader 16 can be used to read the prestressing force applied in the screw connection.

The design of the sensor module 5 described and illustrated here, in particular the annular printed circuit board 9 and the antenna 10 formed thereon, makes it possible to read out the digitized measured values independently of direction, in particular independently of the angle of rotation of the screw nut 1, and thus quickly, ergonomically and safely. The screw nut 1 described here with the sensor module 5 described here enables reliable and ergonomic measurement of the prestressing force both during installation of the screw connection and during subsequent cyclical checks during the entire life cycle of the screw connection, as the sensor module 5 operates passively and does not require a battery.

In the solution described in detail below, the prestressing force applied in the screw connection is determined on the side faces 14 of the main body 6 of the screw nut 1 by means of one or more deformation-detecting sensors 7, in particular in the form of strain sensors. In the following, in particular for the embodiments described here and shown in Figures 1 to 10, it is assumed that the main body 6 of the screw nut 1 is made of metal, since the determination of the prestressing force is particularly important for screw connections with such nuts, although main bodies 6 made of other materials, for example plastic or ceramic, should not be excluded. When the screw connection is tightened, mechanical stresses are built up in the screw nut 1, in particular in its main body 6, and are directly correlated with the applied prestressing force and can be registered as a strain on the respective side face 14.

Figure 1 shows the proposed attachment of a strain gauge sensor as the most common version of a strain sensor and thus of a deformation-detecting sensor 7. Preferably, for reasons of symmetry, the deformation-detecting sensor 7 is positioned centrally or at least as centrally as possible on the side face 14 of the main body 6 of the screw nut 1.

Since under real operating conditions the tightening of the screw connection is usually not exactly uniform due to unevenness on the components involved, due to an inclined assembly and/or due to contamination and therefore does not lead to a rotationally symmetrical distribution of the forces, at least two such deformation-detecting sensors 7 are advantageously provided on the main body 6 to increase the measurement accuracy, and are mounted, for example, on two opposite side faces 14 of the main body 6 of the screw nut 1, as shown in Figures 2, 4, 5 and 8. The respective measured values of the deformation-detecting sensors 7 are then advantageously calculated and evaluated by means of a suitable evaluation algorithm, e.g. simple addition or formation of an average value.

All sensor types commonly used for mounting on metal for measuring strains, compressions and shear forces, e.g. metal strain gauge resistors on foil, semiconductor strain gauge resistors and piezoresistive strain gauges, can be used as deformation-detecting sensors 7, in particular strain gauge sensors, especially if the main body 6 is made of metal. The mounting of the deformation-detecting sensors 7, in particular strain gauge sensors, on the respective side face 14 of the main body 6 of the screw nut 1 is advantageously carried out using a mounting technology normally used for the respective sensor type, for example adhesive bonding with an acrylate, adhesive bonding with an epoxy resin, spot welding or vitrification.

In the simplest design, strain gauge sensors with individual sensor elements are used as deformation-detecting sensors 7, for example, which are mounted in such a way that they measure the force in the longitudinal axis of the main body 6 of the screw nut 1, i.e. in the direction of the axis of rotation of the main body 6 of the screw nut 1. As already explained above, the axis of rotation is the axis about which the screw nut 1 is rotated to produce the screw connection.

However, strain gauge sensors usually have a very low impedance (<= 1 kΩ) and also only provide a very small measurement signal (< 1 mV), which is often also temperature-dependent. For this reason, the individual sensor elements are preferably operated together with reference fixed resistors as a half or full bridge. Alternatively, when mounting a plurality of deformation-detecting sensors 7 designed as strain gauge sensors on the main body 6 of the nut 1, the individual sensor elements can also be connected to form a measuring bridge, which can simplify the evaluation. Alternatively, strain gauge sensors with a plurality of sensor elements that are connected in the form of a half or full bridge and/or have temperature compensation can also be used as deformation-detecting sensors 7, particularly for nuts, especially main bodies 6, with a large overall size. Alternatively, it is also possible to use more complex strain gauge sensors as deformation-detecting sensors 7, e.g. so-called rosette strain gauges, which, however, require multi-channel measuring electronics.

The readout of the determined measured values of the at least one deformation-detecting sensor 7, in particular designed as a strain gauge sensor, or of the plurality of deformation-detecting sensors 7, in particular designed as strain gauge sensors, is advantageously carried out using RFID technology, for example in the HF or UHF range, without contact and without using a battery in the sensor module 5. However, a rechargeable energy store, in particular a capacitor, can be provided, for example, as already mentioned above. The sensor module 5 is powered by an electromagnetic field 20 emitted by the RFID reader 16, as shown in Figure 2. Bidirectional data transmission also takes place via the same electromagnetic field 20, as is usual with RFID technology.

Figure 3 shows a block diagram of a possible embodiment of the sensor module 5, which realizes the determination of the prestressing force in the example shown with two deformation-detecting sensors 7, in particular designed as strain gauge sensors. The sensor module 5 comprises a radio frontend 21, a power management, i.e. an energy management unit 22, a microcontroller 23, in particular designed as a state machine, at least one analogue-to-digital converter 24, also referred to as an analogue-to-digital converter, and the at least one deformation-detecting sensor 7, advantageously a plurality of, in this case two, deformation-detecting sensors 7. The RFID transponder unit 8 includes in particular the radio frontend 21, for example also the power management, for example also the microcontroller 23.

A non-volatile memory commonly used in RFID transponder units 8, for example EEPROM or FRAM, is contained in the radio frontend 21 and is not shown separately. The radio frontend 21 is in particular a communication module of the RFID transponder unit 8, advantageously also comprising the antenna 10, via which in particular the communication with the RFID reader 16 and the reception of the electrical energy transmitted by the RFID reader 16 takes place.

The power management, i.e. the energy management unit 22, includes, for example, voltage stabilization, filtering, voltage monitoring and optionally the aforementioned energy store, in particular in the form of a capacitor, which ensures the electrical energy supply for a predetermined minimum time when the electromagnetic field 20 of the RFID reader 16 is switched off, for example in order to improve a signal-to-noise ratio by this switching off, so that it is also possible to determine the prestressing force in this case.

In order to measure electrical voltages of the deformation-detecting sensors 7, which are designed in particular as strain gauge sensors, the analogue-to-digital converter 24 is provided here with a plurality of signal inputs for the plurality of deformation-detecting sensors 7. Alternatively, a separate analogue-to-digital converter 24 can also be provided for each deformation-detecting sensor 7, in which case the analogue-to-digital converters 24 are advantageously positioned as close as possible to the respective deformation-detecting sensor 7 in order to improve the interference immunity.

Advantageously, all electronic components 25 of the sensor module 5, i.e. in particular the radio frontend 21, the energy management unit 22, the microcontroller 23 and/or the at least one analogue-to-digital converter 24, are arranged on the annular printed circuit board 9. The printed circuit board 9 is made, for example, of FR4 or a similar material or of polymer film, advantageously has a plurality of layers, for example two to six layers, and has, for example, a thickness of approximately 1.0 mm. The printed circuit board 9 advantageously has an at least approximately circular or elliptical contour or a contour comprising a hexagonal outer contour. It is expediently arranged on the end side 11 of the main body 6 of the screw nut 1 that is opposite the application of force. It is advantageously fixedly connected to the main body 6. Advantageously, the printed circuit board 9 is aligned coaxially with the main body 6 of the screw nut 1, as shown in Figure 4. The arrangement of the printed circuit board 9 on the end side 11 opposite the application of force means that it is intended to mount the screw nut 1 in the screw connection in such a way that the end side 11 of the main body 6, on which the printed circuit board 9 is arranged, faces away from the application of force that is generated by this screw connection.

The size of the passage opening 12 in the annular printed circuit board 9 is conveniently dimensioned so that the screw 4 or threaded rod or threaded bolt used for the screw connection can be securely inserted through when the printed circuit board 9 is mounted on the screw nut 1. As this printed circuit board 9 requires a certain amount of installation space, the main body 6 of the screw nut 1 is advantageously of a certain size for use with the sensor module 5 described, so that the application appears to be expedient for nuts > M10, for example. This also applies to the mounting of the deformation-detecting sensors 7 on the side faces 14 of the main body 6 of the screw nut 1, which also require a certain surface area.

In order to miniaturize the size and to increase robustness, all components 25 on the printed circuit board 9 are advantageously fitted on one side and advantageously by means of SMD and/or flip-chip mounting and/or COB mounting, wherein the position of the electronic components 25 on the annular printed circuit board 9 can be selected relatively freely and is thus advantageously optimized with regard to interference immunity and manufacturing costs.

In addition, this annular printed circuit board 9 advantageously serves as a carrier for the antenna 10, which realizes the electromagnetic coupling with the RFID reader 16 and which is very advantageously designed on the printed circuit board 9 as a printed coil ("printed antenna"). The number of windings of this coil is fundamentally dependent on the selected RFID carrier frequency and the size of the main body 6 of the screw nut 1, for example approximately 10 windings.

Furthermore, the printed circuit board 9 is expediently used for the electrical contacting of the deformation-detecting sensors 7, in particular strain gauge sensors, mounted on the side faces

14 of the main body 6 of the screw nut 1, for example by means of soldering, adhesive bonding or wire bonding. Electrical conductor tracks 26, in particular on the printed circuit board 9, between the deformation-detecting sensors 7, in particular strain gauge sensors, and the at least one analogue-to-digital converter 24, as shown here, or the plurality of analogue-to-digital converters 24, are advantageously designed to be of minimal length, i.e. as short as possible, and parallel in order to improve interference immunity. In addition, they are advantageously shielded by copper surfaces arranged above and below them in the printed circuit board 9. The described multiple function of the printed circuit board 9 leads to a considerable reduction in the size and cost of the sensor module 5 and thus of the screw nut 1 in the form of a sensor nut.

The screw nut 1 designed as a sensor nut thus advantageously consists of the main body 6 as the actual nut and the sensor module 5, which in turn advantageously consists of the at least one or more deformation-detecting sensors 7, in particular strain gauge sensors, in particular mounted on a respective side face 14 of the main body 6 of the screw nut 1, the printed circuit board 9 and advantageously the protective sleeve 17 around the deformation-detecting sensors 7, in particular strain gauge sensors, and the printed circuit board 9, as shown in Figure 5. The protective sleeve 17 is, for example, a sheath, a housing and/or a moulding.

The entire structure of the screw nut 1 is advantageously designed here in a monolithic construction in order to obtain a robust, flexible and contactless measuring device for the application of prestress determination in screw connections. This screw nut 1, which is designed as a sensor nut, is advantageously suitable as an object for tightening screw connections in the same way as a standard nut without any fundamental loss of stability, as an original nut is advantageously used as the main body 6 without any changes to its structure. An exception to this is, for example, the embodiment according to Figures 9 and 10, i.e. the arrangement of the respective deformation-detecting sensor 7 in a cavity 15 in the main body 6, since here the respective cavity 15 is formed in the main body 6, for example in a conventional nut, and thus represents a deviation of the main body 6 from this conventional nut.

The described embodiment of the printed circuit board 9 as an annular printed circuit board 9 with a printed annular antenna 10, which encloses the screw opening 13 of the main body 6 and, when the screw connection is produced or already during its production, usually also a part of the screw 4, the threaded rod or the threaded bolt, advantageously leads to an at least approximately rotationally symmetrical structure with respect to the antenna 10, so that the sensor module 5 and thus the screw nut 1, which is designed as a sensor nut, can be read without contact and independently of direction, as shown in Figure 2. This is a key advantage of the solution described here. This property is of particular importance for the use of the screw nut 1 to determine the prestressing force, as it is not possible to predict the angle of rotation at which the required prestressing force will be achieved when the screw connection is tightened and the angle at which the measured sensor values can therefore be read out. With the solution described, this is possible at any angle of rotation of the screw nut 1. This independence of direction makes it considerably easier to use the screw nut 1 to determine the prestressing force.

For tightening the screw connection, open-end spanners or ring spanners or similar tools are used as spanners 3, for example, which must be brought into contact with the screw nut 1, in particular with its main body 6, for this purpose and which produce a considerable force effect on the screw nut 1, in particular on its main body 6, for tightening. In order to ensure the practicable and safe use of these tools, in particular spanners 3, the deformation-detecting sensors 7, in particular strain gauge sensors, are advantageously mounted at a suitable position and with the lowest possible overall height on the main body 6. Alternatively or additionally, the deformation-detecting sensors 7, in particular strain gauge sensors, are advantageously protected from possible loads or damage by these tools, in particular spanners 3, by the aforementioned protective sleeve 17, for example a potting layer or a housing, as shown in Figure 5.

In a possible embodiment of the assembly device 2, it is provided that the shape of the tool to be used, in particular the spanner 3, is modified in a suitable manner, i.e. is adapted to the shape, in particular the circumferential shape, in particular the circumferential contour, of the screw nut 1, in order to ensure easy handling and to avoid possible damage. This modification consists, for example, in the already mentioned design of the screw nut receptacle 18 with the at least one recess 19 formed corresponding to the region of the at least one deformation-detecting sensor 7 projecting beyond the surface of the main body 6 of the screw nut 1 or with the plurality of recesses 19 for receiving the at least one deformation-detecting sensor 7, as shown in Figure 8, i.e. for example in bulges in rear jaws of the spanner 3. This also makes it possible to safely use a spanner 3 designed as an open-end spanner even with two deformation-detecting sensors 7 arranged opposite each other on the main body 6.

Advantageously, the printed circuit board 9 including the protective sleeve 17, for example in the form of a housing or encapsulation, does not protrude beyond the contour of the main body 6, or at least not further than this in the region of the deformation-detecting sensors 7, designed in particular as strain gauge sensors, in order to avoid possible damage caused by the spanner 3 or another tool used.

An overall height of the printed circuit board 9, in particular sheathed in the protective sleeve 17, is advantageously minimal, i.e. as low as possible. For example, it is in the range of a few millimetres. For example, it is approximately 1 mm to 10 mm.

The design described above provides good overall protection of the sensor module 5, including the deformation-detecting sensors 7, which are designed in particular as strain gauge sensors, against damage during handling with the spanner 3. In principle, the assembly of the nut 1 described here is therefore advantageously no different, or at least not significantly different, from the assembly of a comparable conventional nut without sensor module 5 in terms of the tools and effort required. Assembly is therefore still very simple, reliable and cost-effective, for example using a spanner 3.

Optionally, the at least one deformation-detecting sensor 7 or the plurality of deformation-detecting sensors 7, in particular each formed as a strain gauge sensor, can be mounted in a respective cavity 15, as already described above and shown in Figures 9 and 10, i.e. in a recess in the respective side face 14 of the main body 6, so that the respective deformation-detecting sensor 7 is even better protected. This cavity 15 is advantageously formed in the main body 6 up to the printed circuit board 9 in order to also protect electrical connecting lines 27 of the respective deformation-detecting sensor 7 to the printed circuit board 9, as shown in Figures 9 and 10. Advantageously, the respective deformation-detecting sensor 7, including its connecting lines 27, is installed flush in the respective side face 14 of the main body 6 of the screw nut 1, so that damage to the respective deformation-detecting sensor 7 by the spanner 3 or another tool can be ruled out, at least virtually.

It is particularly advantageous when using the screw nut 1 if the prestressing force can also be constantly determined and displayed during tightening. For this purpose, as already mentioned above, it is provided, for example, that the RFID reader 16 is fixedly connected to the spanner 3 or is releasably connectable or connected to the spanner 3, in particular in the case of the assembly device 2, i.e. the spanner 3 to be used can optionally be provided with the RFID reader 16, which is fixedly or releasably connected to it. This RFID reader 16 can, for example, have a display unit 28, in particular a display, for the measured value display and/or can transmit the measured values, for example via a cable and/or wirelessly, for example via Bluetooth or another wireless technology, to another device, for example a mobile phone, in particular a smartphone, or a portable computer, for example a tablet or a notebook, so that they can be displayed and/or stored there.

An additional significant advantage of determining the prestressing force of the screw connection on the main body 6 of the screw nut 1, which is advantageously designed as a conventional nut, is that nuts are a cost-effective component offered in standardized sizes and designs and the product variability of which is significantly lower than that of screws. This means that nuts, which are used as the main body 6 for the screw nut 1 described here and are fitted with deformation-detecting sensors 7, in particular strain gauge sensors, in accordance with the design described here, can be manufactured more cost-effectively and in larger series than, for example, screws 4 or even special screws. Compared to other solutions offered or conceivable to date, the determination of the prestressing force acting in the screw connection with the screw nut 1 provided with the sensor module 5 described here allows effective mass production, warehousing and marketing of this screw nut 1 designed as a sensor nut for standardized nut applications. In addition, it is much easier to replace the screw nut 1, for example in the event of a failure and/or to recalibrate the respective deformation-detecting sensor 7, than to replace a screw 4 or a threaded bolt.

In addition to using the at least one or the respective deformation-detecting sensor 7, in particular strain gauge sensor for deformation measurement, in particular strain measurement, the sensor module 5 has, for example, at least one or more further sensors. This at least one further sensor or this plurality of further sensors is/are then advantageously also operated and read out using RFID technology, i.e. in particular they also receive electrical energy from the RFID reader 16 via the electromagnetic field 20, analogously to the respective deformation-detecting sensor 7, and the sensor results are also read out using the RFID reader 16.

For example, at least one temperature sensor or a plurality of temperature sensors are arranged as additional sensors on the printed circuit board 9 of the sensor module 5 or in the region, in particular in the immediate vicinity, of the deformation-detecting sensors 7 or the respective deformation-detecting sensor 7. A temperature measured with the at least one temperature sensor can then be used, for example, for temperature compensation of the signals measured with the respective deformation-detecting sensor 7, which is designed in particular as a strain gauge sensor.

Alternatively or additionally, at least one three-dimensional acceleration sensor or a plurality of three-dimensional acceleration sensors based on MEMS are possible as further sensors. This is relatively easy to implement. This respective additional sensor is then arranged, for example, on the printed circuit board 9, which is designed in particular as an FR4 printed circuit board, and can detect, for example, even slight changes in the position of the sensor module 5 and thus of the measurement object, i.e. the screw nut 1. This information can be particularly relevant for movable measurement objects, which is the case with screw nuts 1. Alternatively or additionally, such MEMS sensors also enable the measurement of accelerations and vibrations. Alternatively or additionally, such a MEMS sensor with an additional sensor for measuring the angular velocity or the magnetic field strength, including the earth's magnetic field, can be provided on sensor module 5, for example.

Since larger metal surfaces in the immediate vicinity of a coil generally lead to an influence on this coil with regard to its inductance and its quality, this also applies to the antenna 10 on the printed circuit board 9 of the sensor module 5, which is advantageously designed as a coil, in particular as a printed coil, which is used for coupling with the RFID reader 16 and thus forms a parallel resonant circuit together with a capacitor, as is usual. The metal of, for example, a washer used in the screw connection and the metal of, in particular, the part of the screw 4 or the threaded bolt or the threaded rod that passes through the passage opening 12 in the sensor module 5 detunes the resonant frequency of the resonant circuit and significantly reduces the quality of the resonant circuit, in particular due to eddy current losses occurring in these metals and any permeable materials used, for example steel, which has a negative effect on the energy and data transmission via the RFID coupling. The occurring detuning of the resonant frequency can be corrected by an appropriate adjustment.

To avoid an excessive reduction in the quality of the resonant circuit and thus the maximum possible reading distance with the RFID reader 16 due to the metal, a minimum distance of the antenna 10 on the printed circuit board 9, which is designed as a coil, to the main body 6 and to the screw opening 13, in particular to the thread in the screw opening 13, is advantageously provided, which is, for example, in the range of approximately 1 mm. The design of the antenna 10 in the form of a coil on the printed circuit board 9 of the sensor module 5 is thus such that the windings of the coil on the annular printed circuit board 9 are located outwards to the greatest possible extent, for example as far outwards as possible, and are also located as far as possible on at least one printed circuit board layer of the printed circuit board 9, which is located far away, for example furthest away, from the main body 6, as shown in Figures 4, 6, 7, 9 and 10.

In possible embodiments, a non-electrically conductive, in particular electrically insulating, at least high-impedance layer 29 is arranged between the printed circuit board 9 and the main body 6, in particular its end side 11, on which the sensor module 5 is arranged, as shown in Figures 7, 9 and 10. This layer 29 increases the distance between the printed circuit board 9 and the metal of the main body 6 of the screw nut 1. Alternatively, this layer 29 can be made of a permeable material, for example, which can effectively reduce the eddy currents induced in the metal by distorting the field lines. A suitable permeable material is used for this purpose, which does not exhibit excessive losses even at a frequency of 13.56 MHz, for example, i.e. exhibits only predetermined low losses. This material can be produced, for example, by mixing a suitable ferrite powder into a flexible plastic. This layer 29 is thus made of plastic, for example, to which a ferrite powder is added.

In addition to realizing the measurement function described, the use of RFID technology offers significant further advantages. In particular, the use of the non-volatile data memory, especially in the RFID transponder unit 8, for storing information such as identification number, calibration data of the sensors, manufacturer and type information of the screw nut 1 as well as usage data is very advantageous. In principle, RFID technology also offers the possibility of parallel measurement and reading of a plurality of screw nuts 1 designed as sensor nuts, which are located on the same side in the electromagnetic field 20 of the RFID reader 16, thanks to the anti-collision algorithms that are usually implemented.

Furthermore, the special embodiment of the RFID technology used, for example, as an NFC interface offers the possibility of reading out the measurement data with a mobile phone, in particular a smartphone, or similar devices with an NFC interface, for example with a portable computer, in particular a tablet or notebook, and even being able to display and process it particularly easily when transmitted as an NDEF message.

LIST OF REFERENCE SIGNS

1	screw nut
2	assembly device
3	spanner
4	screw
5	sensor module
6	main body
7	deformation-detecting sensor
8	RFID transponder unit
9	printed circuit board
10	antenna
11	end side
12	passage opening
13	screw opening
14	side face
15	cavity
16	RFID reader
17	protective sleeve
18	screw nut receptacle
19	recess
20	electromagnetic field
21	radio frontend
22	energy management unit
23	microcontroller
24	analogue-digital converter
25	electronic component
26	conductor track
27	connecting line
28	display unit
29	layer

Patentkrav

1. Skruemøtrik (1) med et sensormodul (5) til bestemmelse af en forspændingskraft af en skrueforbindelse, hvor sensormodulet (5) omfatter i det mindste en på et grundlegeme (6) for skruemøtrikken (1) anbragt deformationsdetekteringssensor (7) til detektering af en deformation af skruemøtrikkens (1) grundlegeme (6) og en RFID-transponderenhed (8), og hvor en printplade (9) for sensormodulet (5), på hvilken der er udformet en antenne (10) for RFID-transponderenheden (8) og et elektronisk kredsløb for sensormodulet (5), og som er koblet elektrisk ledende med den i det mindste ene deformationsdetekteringssensor (7), er anbragt på en frontflade (11) af grundlegemet (6),
kendetegnet ved, at printpladen (9) er udformet ringformet, hvor en lysning af en gennemføringsåbning (12) i printpladen (9) er i det mindste lige så stor som en lysning af en skrueåbning (13) i grundlegemet (6).

2. Skruemøtrik (1) ifølge krav 1,
hvor printpladen (9) er udformet cirkulært eller elliptisk eller med sekskantet ydre kontur.

3. Skruemøtrik (1) ifølge et af de foregående krav,
hvor den i det mindste ene deformationsdetekteringssensor (7) er anbragt i området af en ydre omkredsside af grundlegemet (6)

4. Skruemøtrik (1) ifølge krav 3,
hvor den i det mindste ene deformationsdetekteringssensor (7) er anbragt på en sideflade (14) eller er anbragt i en kavitet (15), som er udformet i en sideflade (14), eller er anbragt i en aksial boring i området ved en kant mellem to mod hinanden tilstødende sideflader (14).

5. Skruemøtrik (1) ifølge et af de foregående krav,
hvor den i det mindste ene deformationsdetekteringssensor (7) er udformet som en sensor til detektering af tøjninger, stukninger og/eller forskydningskræfter, især som en

tøjningssensor, især som en strain gauge sensor.

6. Skruemøtrik (1) ifølge et af de foregående krav, hvor RFID-transponderenheden (8) har et energilager, især em kondensator.

7. Skruemøtrik (1) ifølge et af de foregående krav, hvor antennen (10) er anbragt eller udformet som en spole på printpladen (9).

8. Skruemøtrik (1) ifølge krav 7, hvor antennen (10) er udformet som en printet spole på printpladen (9).

9. Skruemøtrik (1) ifølge et af de foregående krav, hvor sensormodulet (5) omfatter flere deformationsdetekteringssensorer (7), som især er anbragt ensartet fordelt omkring en ydre omkreds på grundlegemet (6).

10. Skruemøtrik (1) ifølge et af de foregående krav, omfattende et beskyttelseshylster (17) for sensormodulet (5).

11. Montageanordning (2) med en skruemøtrik (1) ifølge et af de foregående krav og en skruenøgle (3), hvor et RFID-læseapparat (16) er fast forbundet med skruenøglen (3) eller kan forbindes eller er forbundet løsbart med skruenøglen (3), og/eller hvor en skruemøtrikoptagelse (18) på skruenøglen (3) har i det mindste en udtagning (19) til optagelse af den i det mindste ene deformationsdetekteringssensor (7) for skruemøtrikken (1), hvor denne i det mindste ene udtagning (19) er udformet korresponderende med et over en overflade af skruemøtrikkens (1) grundlegeme (6) fremstående område af den i det mindste ene deformationsdetekteringssensors (7).

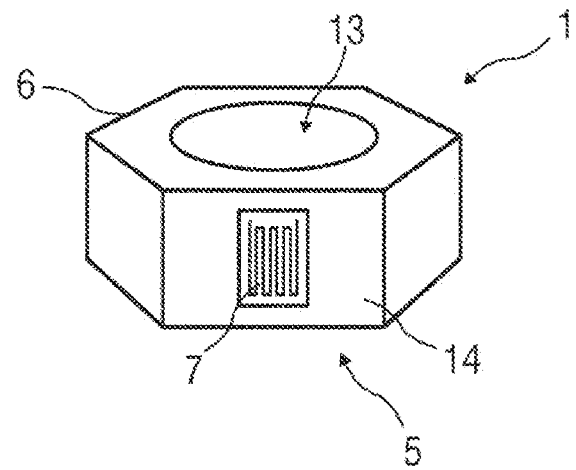

FIG 1

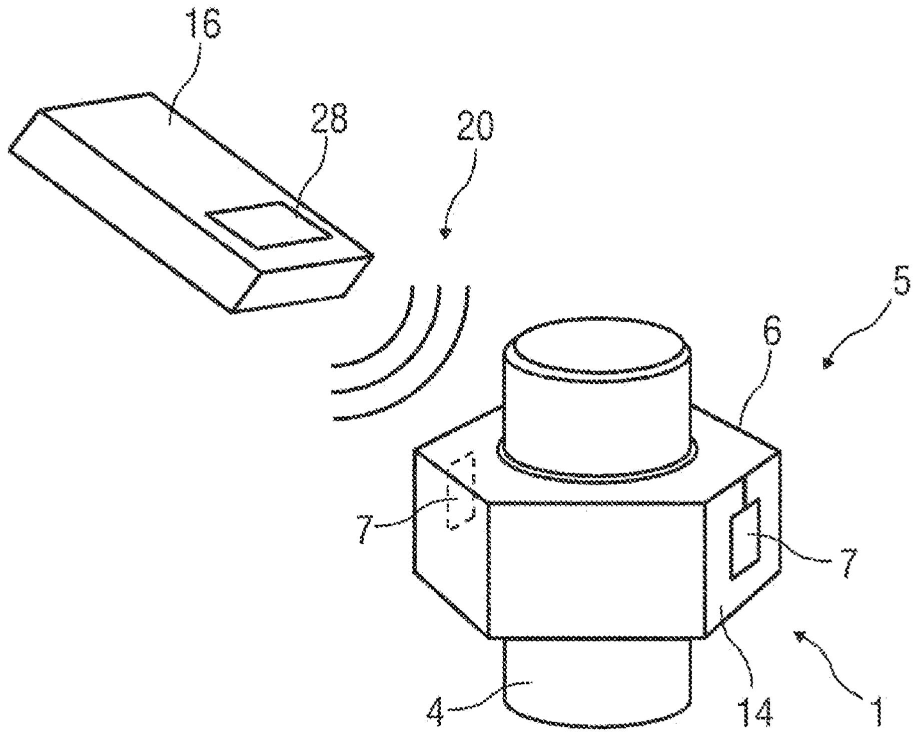

FIG 2

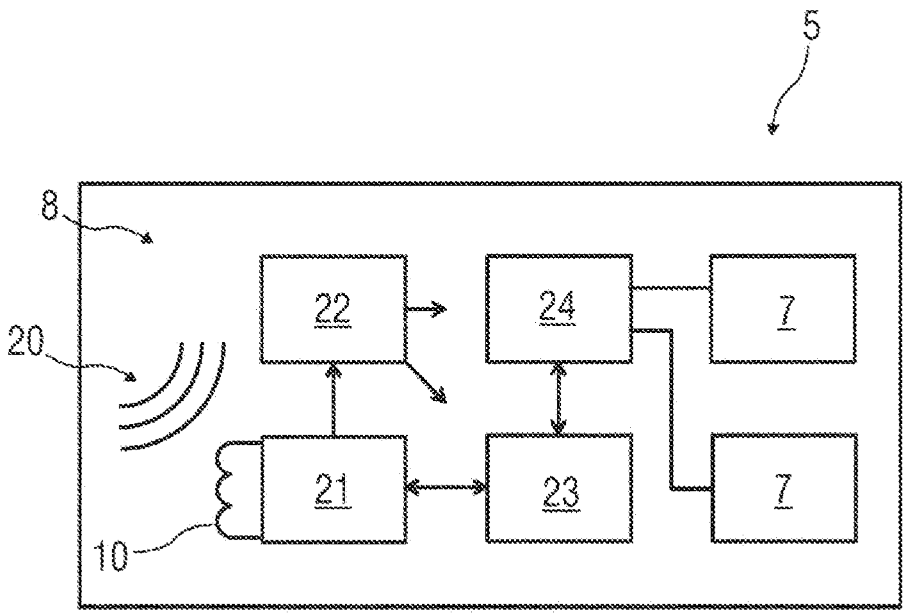

FIG 3

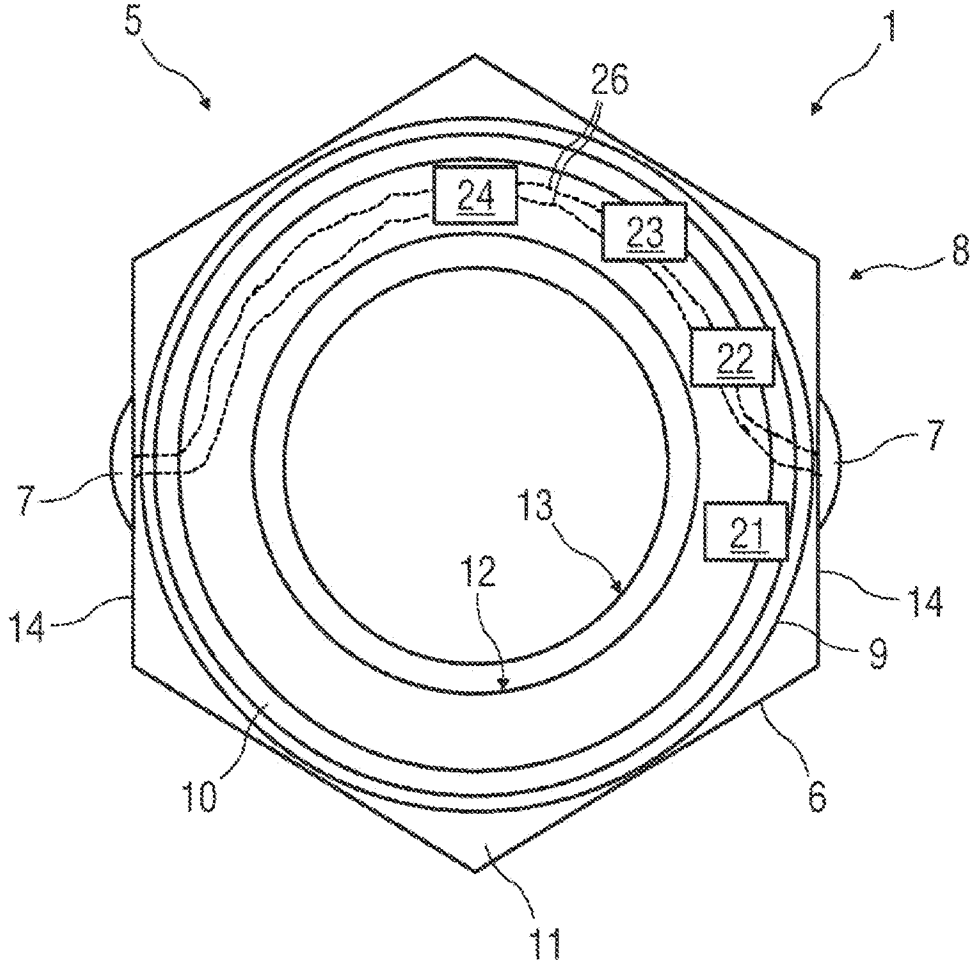

FIG 4

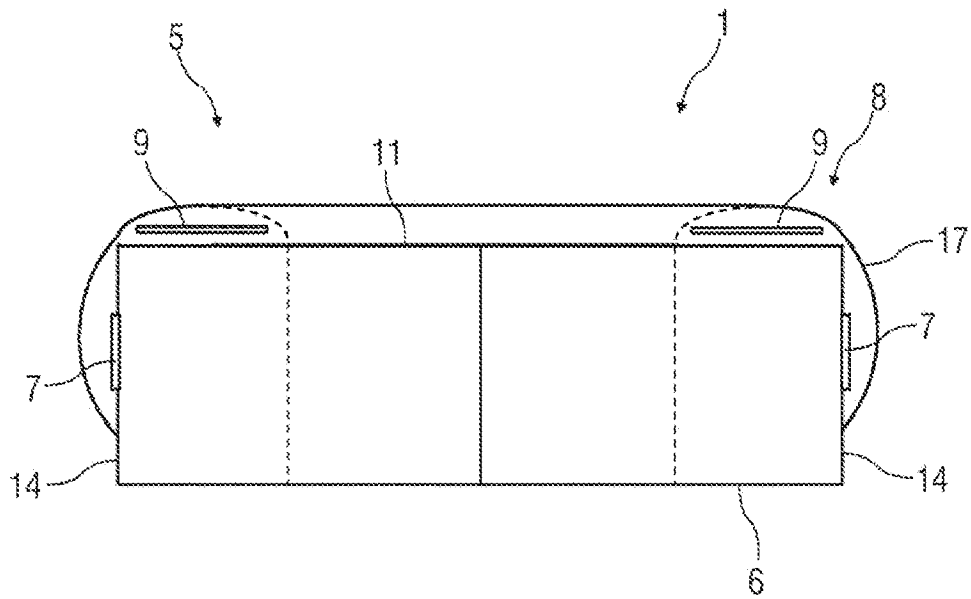

FIG 5

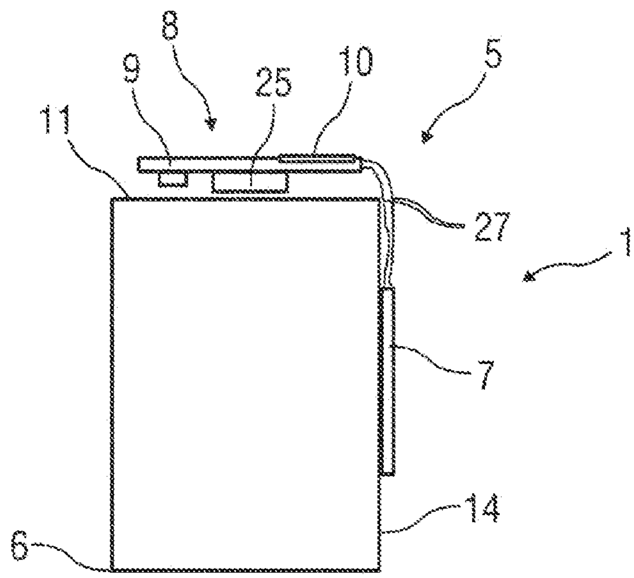

FIG 6

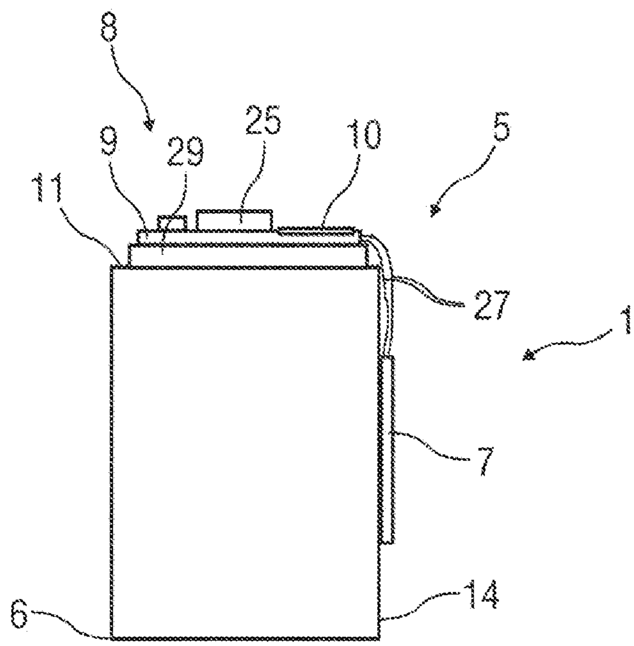

FIG 7

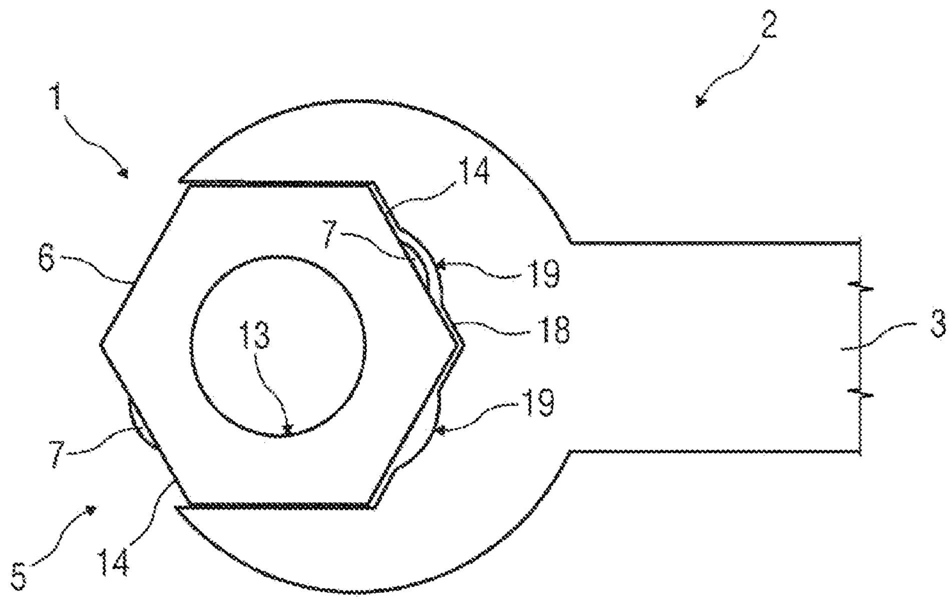

FIG 8

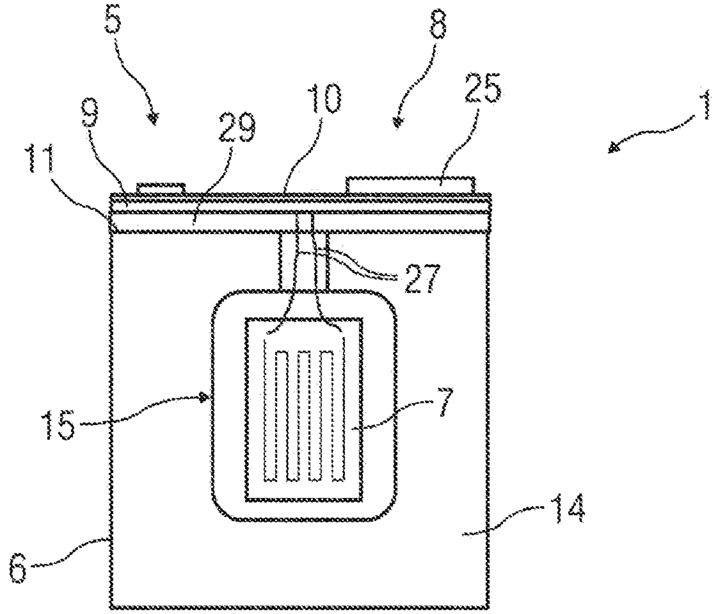

FIG 9

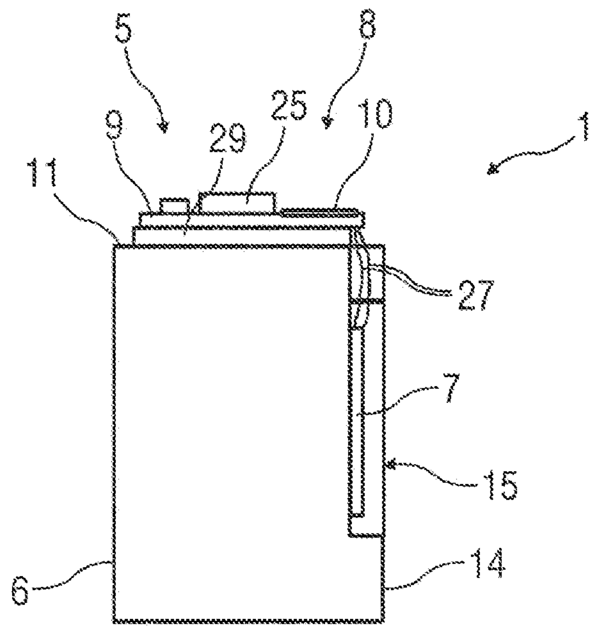

FIG 10