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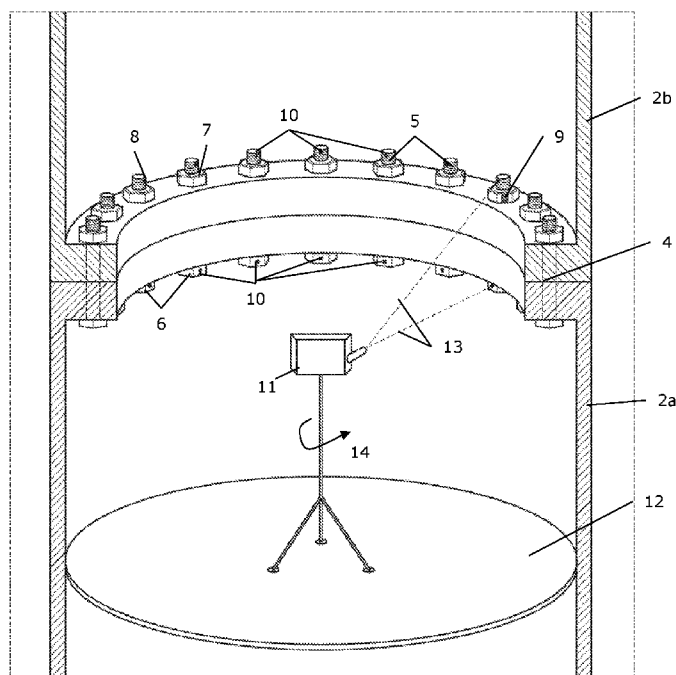


Fig. 2

(57) Abstract: The invention relates to a method of assembly and maintenance of a flange connection (4) of two flanges connected by a number of bolts (5). The method comprises the steps of providing each bolt with a reference mark (10) at each opposite end (6,8) of the bolt and measuring on each bolt a baseline distance between the reference marks at a pre-defined tensioning of the bolt. When positioned to connect the flanges, the bolts are tensioned and a 3D non-contact measuring equipment (11) is positioned such as to have a line of sight to the reference marks on the bolts. The equipment then determines an elongation change for each bolt based on the difference between the current distance and the baseline distance. The invention further relates to a bolt comprising a reference mark at each opposite end and optionally an identifier comprising an ID of the bolt.



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PRE-TENSIONING OF BOLTS

FIELD OF THE INVENTION

The present invention relates to a method of assembly and maintenance of a flange connection of two flanges connected by a number of bolts. The invention
5 furthermore relates to a bolt prepared for such method.

BACKGROUND OF THE INVENTION

For a bolted connection it is critical that the bolts have been given the correct pre-tension by the tensioning of the bolts. Pre-tensioning (also called preload) is the stretching of the bolt and corresponding compression of the surfaces and
10 any washers which have been bolted together. If the pre-tensioning is too small, the bolts are exposed for exceeded load-patterns and may break over relatively short time due to fatigue stress. On the other hand, if the pre-tensioning is too large, the bolts can be exposed to plastic deformation and consequently break.

In wind turbines, bolt connections are often used in flange connections between
15 tower sections or in connecting the tower to the foundation. Due to the sizes, weight and loads involved in modern wind turbines, a considerable number of bolts and of considerable sizes are used in the flange connections. As an example, a typical bolt in tower flange connection may have a length of 350 mm, a diameter of 54 mm, and a weight of around 18 kg. That is to say, the
20 bolts as well as the machinery for the tightening the bolts are not easily handled. Additionally, the bolts need to be positioned and tightened often under harsh and difficult working conditions. Here, a failure of a bolt connection may be fatal to the entire wind turbine ultimately causing the tower to crash.

A known method of pre-tensioning a bolt is by the so-called torque-tension
25 method which includes applying a specific calculated torque to the nut. The nut is lubricated with i.e. MoS₂ which results in a specific friction between bolt and nut. This friction counterbalances the requested torque. It has however been

observed in some cases that a bolt is not torqued correctly by this method which is believed to be caused by an insufficient lubrication during the torque process.

An alternative method for measuring the tensioning of a bolt is by means of ultrasound. Ultrasonic bolt load measurements of bolt preload are carried out by introducing a sonic pulse at one end of the fastener and accurately measuring the returning echo known as time of flight (TOF) which is converted into a length measurement of the bolt. The pre-tensioning of the bolt can then be determined from the measurement of the elongation of the bolt caused by the tensioning. However, although the ultrasound measurements can provide accurate results, the method requires some of the measuring equipment to be positioned directly on each bolt end and need to be removed during tensioning and repositioned. Further, the measurement method requires flat and parallel bolt ends and with a reasonable surface finish.

OBJECT AND SUMMARY OF THE INVENTION

It is an object of embodiments of the invention to provide a method of measuring tension of a large number of bolts in a flange connection in a short time.

So, in a first aspect the present invention relates to a method of assembly and maintenance of a flange connection of two flanges connected by a number of bolts, the method comprising:

- providing each bolt with a reference mark at each opposite end of the bolt;
- measuring on each bolt a baseline distance between the reference marks at a pre-defined tensioning of the bolt;
- tensioning the bolts when positioned to connect the flanges;
- positioning a 3D non-contact measuring equipment such as to have a line of sight to the reference marks on the bolts;
- measuring on each bolt the distance between the reference marks by means of the 3D non-contact measuring equipment thereby obtaining a current distance on each bolt; and

- determining for each bolt an elongation change based on the difference between the current distance and the baseline distance.

By the provision of a reference mark at opposite ends of each bolt, the distance between the marks can be determined at different tensioning and thereby the elongation change or change of length caused by the change of tensioning of each bolt. By having determined the elongation change of each bolt, the current tensioning of each bolt is known or at least if the current tensioning is larger or smaller than a desired tensioning or within an acceptable range.

The elongation is determined based on the difference between the current distance and the baseline distance. The elongation is the change of distance in a direction parallel to the centre axis of the bolt between normal planes that intersects the reference marks between a baseline state and a current state. The distance may coincide with the elongation of the bolt if the reference marks are located on a line parallel to the centre axis of the bolt or the distance may be different and the elongation to be determined based on the geometrics of the position of the reference marks.

Further, by the use of a 3D non-contact measuring equipment, the distance between the marks of all the bolts can be measured with the equipment staying in the same set-up position simply with a line of sight to the bolts and without physical contact with the bolts. This simplifies the measurement method significantly in comparison to known methods involving the placing of measuring equipment on each individual bolt and measuring the tension of the bolt before moving the measuring equipment to the next bolt. This makes the method especially advantageous when applied to a flange connection comprising a relatively large number of bolts and further advantageous for relatively large bolts and in working environments where the handling and the handling time of the bolts is preferably to be kept at a minimum. This is for example the case for flange connections in wind turbines such as between tower sections, between the tower and the foundation or in the nacelle. As an example a typical bolt used in a typical flange connection in a wind turbine tower is a M54 with a diameter of

54 mm a length of 350 mm and weight of about 18 kg and with for example a total number of 100-150 bolts for connecting the two flanges.

The flange connection that the method can be applied to includes both horizontal turbine tower flanges and vertical tower flanges, more specifically wind turbine tower flanges. The horizontal flanges are typically located between tower sections and the vertical flanges are typically located between tower segments, where at least two tower segments make up a tower section. An example of such a tower is described in WO 2004/083633 A1. Other non-limiting examples of flange couplings are couplings between axles or flange connection between a wind turbine blade and hub.

The method according to the invention further advantageously enables the measurements of the elongation change of each or all bolts to be quickly repeated a number of times as desired. Further, additional tensioning of all or some of the bolts can be performed as desired in between measurements without affecting the measuring equipment i.e. without any need for dismantling or repositioning of the measuring equipment.

An added advantage of the method according to the invention is that the bolts can be tensioned in a predefined pattern without affecting the position of the measuring equipment.

The method according to the invention may be applied for either assembly or maintenance of a flange connection or for both. Maintenance may include servicing, controlling, and optionally adjusting the tensioning of some or of all the bolts if required. The flange connection may comprise a connection of inwardly or outwardly facing flanges and of flanges of any shape such as circular, oval, straight or curved.

The step of providing each bolt with reference marks may be performed on site prior to positioning the bolts in the flange connection or on any other time such as during manufacture of the bolts. The reference marks may comprise any sort of visual markings such as painted dots, indentations, scratches and the like.

Preferably the reference marks are made such as to withstand humidity and to stay visible after handling of the bolts and at least for some time. The reference marks may be provided by the same method or by different methods. The reference marks are provided at opposite ends of each bolt such as on the nut
5 and on near the end of the threaded end (or threaded ends for a stud bolt).

Because of the measuring of the baseline distance between the reference marks at a pre-defined tensioning of each bolt, the reference marks need not be positioned precisely or on pre-determined precise positions on the bolt whereby the reference marks can be applied to the bolts very easily and fast without any
10 special arrangements or requirements to environmental conditions such as temperature etc.

The baseline distance is measured as the distance between the reference marks on a bolt at a pre-defined tensioning of the bolt such as being un-tensioned (that is in a relaxed state) or subjected to a known pre-defined tensioning. In this
15 way the baseline distance may for example be measured on the bolt without any nut(s) or as positioned in the flange with a nut only loosely screwed onto the bolt (corresponding to the bolt being in a relaxed state with a zero tensioning) or may be tensioned to some pre-defined value by any type of tensioning equipment. The baseline distance may be the same for all or for some of the
20 bolts in the flange connection of may attain different values.

The tensioning of the bolts when positioned to connect the flange may be performed by any traditionally used tensioning equipment such as by rotation of the nut with manually operated wrenches, hydraulic wrenches, electrical wrenches and the like or stretching of the bolt followed by rotation of the nut
25 and subsequently release of the bolt. The tensioning may preferably correspond to the tensioning assumed to be needed to obtain the desired pre-tensioning of the bolts in which case the further method steps of determining the elongation change provides for a control that indeed the desired pre-tensioning has been achieved. Alternatively the tensioning may be to some other potentially
30 unknown tensioning value in which case the further method steps of determining

the elongation change provides for a means of determining the actual tension or if the tensioning is above or below a certain threshold tension.

The tensioning of the bolts when positioned to connect the flanges may be performed just prior to measuring the current distance of the bolts or may
5 alternatively have been performed longer time before. As an example, the tensioning may have been performed during assembly of the flanges whereas the measuring of the current distance may be performed at a later time for example during maintenance or inspection. In this way the method according to the invention may be performed to ensure the correct pre-tensioning of the bolts
10 during assembly of the flange connection. Additionally or alternatively, the method may be performed to control and verify the pre-tensioning of the bolts during inspection or maintenance of an existing flange connection.

The current distance between the reference marks is measured by means of a 3D non-contact measuring equipment such as for example a laser scanner or a
15 camera and using photo trigonometry. The 3D non-contact measuring equipment advantageously can measure on the bolts without being in direct physical contact with each bolt. Hereby the bolts can be handled and e.g. further tensioned and the measurements can be repeated without the need for dismantling or repositioning of the measuring equipment. Further, the 3D non-
20 contact measuring equipment can perform the measurements on all the bolts fast and simple in one or optionally a number of sweeps or recordings and in a very short time without the need for repositioning of the measuring equipment in-between measurements.

The 3D non-contact measuring equipment is positioned such as to have a line of
25 sight to the reference marks on the bolts. This may if needed involve turning or repositioning one or more of the bolts such that the reference marks are within sight to the 3D non-contact measuring equipment and/or repositioning the 3D non-contact measuring equipment to have line of sight to a group of the bolts at a time depending on the geometry on the flange and on any other objects
30 potentially obstructing part of the lines of sight. For circular or round inward flange connections, the 3D non-contact measuring equipment is preferably

positioned centrally thereby obtaining a line of sight to all the bolts in the flange connection. By the use of a 3D non-contact measuring equipment the distance from the equipment to the bolts need not be the same which facilitates the performance of the method greatly.

- 5 The elongation change determined based on the difference between the current and the baseline distance expresses how much the bolt has been tensioned. By the proposed method, the exact dimensions of the bolt need not be determined nor the exact change in elongation of the bolt as such, only the relative change in distance between the reference marks, which simplifies the method and the
- 10 requirements to the measuring equipment. Further, this simplifies the marking of the bolts as the reference marks need not be positioned with high accuracy or on precise positions.

The elongation change may be positive or negative or even zero depending on the tensioning of the bolt between the determination of the baseline distance

15 and the current distance, and corresponding to the bolt having been tightened or loosened.

In an embodiment the method comprises the further steps of:

- determining for each bolt a tensioning operation as a function of the elongation change of the bolt, and
- 20 - adjusting the tensioning of each bolt in accordance with the tensioning operation of the bolt.

The tensioning operation may comprise any of tightening, loosening or not changing the tensioning the bolt. Because the elongation change directly reflects the change in tensioning of the bolt from the pre-defined tension to the current

25 tensioning, the elongation change can be used as a precise indication of the current pre-tension of the bolt and if its pre-tension is within, above or below a desired level. Because of the use of the 3D non-contact measuring equipment, the tensioning operation can be determined for all the bolts at the same time and provided to the one or more operators. Hereby the tensioning of the bolts

can then be adjusted all at once and by more people if so desired reducing the time needed for performing the assembly or maintenance.

In an embodiment, the tensioning operation comprises tightening the bolt if the determined elongation change is below a pre-defined lower threshold and/or loosening the bolt if the determined elongation change is above a pre-defined upper threshold. Hereby is obtained that a certain minimum pre-tension of the bolt is ensured corresponding to the lower threshold for the elongation change and likewise that the bolt is not tensioned too much corresponding to the upper threshold for the elongation change. Likewise, according to an embodiment, the tensioning operation comprises keeping the tension of the bolt unchanged if the determined elongation change is within a pre-defined range. The pre-defined lower threshold, the pre-defined upper thresholds, and the pre-defined range may each or some of them be determined by experiments conducted on bolts of the same type or additionally and/or alternatively determined numerically.

Hereby is obtained that each of the bolts in the flange connection is given the desired amount of pre-tensioning neither too small nor too large and thereby a strong flange connection with a reduced risk of bolt breaking.

According to further embodiment of the invention, the tension operation of a first bolt is further determined as a function of the elongation change of one or more of the other bolts in the flange connection. Hereby is obtained a more precise tensioning of the bolts in a flange connection as the optimal pre-tension of one bolt may be given in dependence on more parameters such as for example the pre-tension of two or more of the neighbouring bolts as well, or may be determined such as to obtain a certain pre-determined average pre-tension of all or groups of the bolts in the connection. Because of the use of the 3D non-contact measuring equipment, all bolt elongation changes are advantageously available in determining the tensioning operation of each bolt, and the tension operations for all the bolts can be determined at the same time as opposed to potentially needing to be determined on a bolt-by-bolt basis as by traditional methods.

In an embodiment of the invention, each bolt further comprises an identifier comprising an ID of the bolt, and wherein the method further comprises for each bolt detecting and storing the ID together with the measured baseline distance. Hereby, the information on baseline distance can be registered and stored for each bolt in the flange connection and easily retrieved at any later time when

determining the current distance of the bolt. In this way the data is easily and by simple means related to each specific bolt in the bolt connection and can be easily stored, retrieved, and used for documentation purposes of for later adjustment or control of the tension of each specific bolt. This is especially advantageous for larger flange connections involving a relatively large number of bolts such as between tower sections in wind turbines where a typical flange connection is often seen to have in the amount of 100-150 bolts or even more. The identifier may for example be a 1D or 2D barcode such as a QR or matrix code.

In an embodiment of the invention the identifier may be a soft identifier stored in the memory of the measuring equipment. A first bolt having an identifier is located in the flange connection. The 3D non-contact measuring equipment is positioned in relation to the first bolt. The location of all other bolts is referenced in relation to this first bolt. For example the bolt number in a counter clockwise/clockwise direction from the first bolt. The tension measurement is stored for each bolt numbered in relation to the first bolt. For multiple flange connections, each flange connection may have a unique identifier.

According to an embodiment of the invention, the pre-defined tension is zero and the bolt is in a relaxed state when measuring the baseline distance. Hereby, the baseline distance can advantageously be measured in any convenient location and by any convenient equipment such as simply by a caliper or the like. Further, the baseline distance can in this way be determined without having tensioned the bolt.

In an embodiment, the method further comprises positioning the bolts in the flanges prior to the step of measuring the baseline distance and wherein the measuring of the baseline distance is performed by means of the 3D non-contact measuring equipment. This provides for a fast and simple way of measuring the baseline distance of a relatively large number of bolts. In this way the 3D non-contact measuring equipment is positioned first and the two sets of measurements (for the baseline and the current distance measurements) are performed without necessarily moving or repositioning the 3D non-contact

measuring equipment in-between. Furthermore, by positioning the bolts in the flanges before measuring the baseline distances, the book keeping of the information and measurements of each bolt is more simple and with less risk of errors.

- 5 In an embodiment of the invention, the current distance is measured on at least a part of the bolts prior to adjusting the tensioning of the part of the bolts. The advantages hereof are as mentioned in the previous that the method hereby provides for the adjustment of the tensioning of more bolts at the same time. Further, the tensioning operation of one bolt can then easily be determined as a
10 function of the elongation change of other bolts as well.

In an embodiment of the invention, the step of measuring the baseline distance is performed at a time prior to or during assembly of the flange connection and the step of measuring the current distance and adjusting the tensioning of each bolt is performed at a later time during assembly or maintenance of the flange
15 connection. The advantages hereof are as described in the previous.

According to a further embodiment of the invention, the reference marks of the bolts are provided by application of paint and/or by the making of indentations. This provides for a simple and relatively fast way of marking the bolts without special equipment or requirements to special facilities or the like.

- 20 In an embodiment, the measuring of the distance between the reference marks by means of the 3D non-contact measuring equipment comprises measuring by means of laser beam or photo trigonometry. Hereby the current distance and optionally the baseline distance can be measured relatively fast yet accurately on a large number of bolts without having to move or reposition the equipment
25 in-between measurements. Further, the equipment and the measurement methods are relatively simple to use and can be used under not so favourable working and weather conditions such as for example many meters up in the air, in an offshore wind turbine tower.

According to an embodiment of the invention, at least one of the flanges in the flange connection forms part of a tower section, a foundation section, or a nacelle of a wind turbine. As previously mentioned, such flange connections in modern wind turbines involve a large number of very large and correspondingly heavy bolts which are difficult and time consuming to handle and very often under difficult working conditions. Furthermore, the requirements to the pre-tensioning of the bolts are very specific and strict in order to avoid potentially critical and severe damaging to the wind turbine due to the large and very complex loadings on e.g. the wind turbine towers. Therefore the method according to the invention is especially advantageous for flange connections in wind turbines because it is fast and simple to perform also under difficult working and weather conditions and can be repeated as desired for later service and maintenance.

In a further aspect the present invention relates to a bolt comprising a first threaded end for receiving a nut and an opposite second end, the bolt comprising a reference mark positioned at each opposite end and wherein the reference marks are positioned such as to have a line of sight to one single point distant to the bolt. The reference marks are hereby positioned on the same side of the bolt. By the provision of the reference marks at each opposite end, the distance between the reference marks can be measured both when the bolt is un-tensioned and optionally without a nut, and when the bolt is tensioned and positioned in for example a flange.

Both reference marks are positioned on the bolt such as to have a line of sight to and be visible from e.g. a 3D non-contact measuring equipment positioned next to or at a distance from the bolt. Hereby the distance between the reference marks can be measured by the 3D non-contact measuring equipment. This makes the bolt advantageous for use in the method described in the previous and with the advantages as described in relation to the method.

The bolt may comprise a bolt head or a second thread for receiving a nut at the second end. If the bolt comprises a bolt head, one of the reference marks may be positioned on a surface of the bolt head.

In an embodiment, the bolt further comprises an identifier comprising an ID of the bolt, which allows for simple, reliable and fast identification of each individual bolt. Hereby measurements can be made on the same bolt with long time or even years in between and data can be reused and documented reliably.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following different embodiments of the invention will be described with reference to the drawings, wherein:

Fig. 1 is a sketch of two tower sections of a wind turbine being assembled,

- 5 Fig. 2 is a sketch of a flange connection in a wind turbine tower and of the method of pre-tensioning by use of a 3D non-contact measuring equipment according to an embodiment of the invention,

Fig. 3 illustrates one bolt according to an embodiment of the invention and positioned in a flange connection, and

- 10 Fig. 4 illustrates an embodiment of the measurement method.

DETAILED DESCRIPTION OF THE DRAWINGS

- Figure 1 illustrates two tower sections 2a, 2b of a wind turbine 1 being assembled. Here, a first structural part 2a in the form of a tower section is positioned and in place and a second structural part 2b, such as another tower section or the nacelle (not shown) of a wind turbine, is suspended from a crane 3 and is to be connected with the first structural part 2a in a flange connection.
- 15

- Figure 2 illustrates such flange connection 4 of two wind turbine tower sections, 2a, 2b. The flanges are connected by a large number of bolts 5 (of which only a few are shown for simplicity), which here comprise a bolt head 6 in on end and are tightened by a nut 7 at their other opposite threaded end 8. Each bolt 5 comprises a reference mark 10 at each opposite end of the bolt such as on the bolt head 6 and at the threaded end 8 of the bolt. Each bolt may further comprise an identifier 9 comprising ID information of the bolt in the embodiment shown the ID information of the bolt is located on the nut. In other
- 20
- 25
- embodiments the ID information is located on the head of the bolt, see fig. 3. Moreover a flange connection may have a first bolt with ID information and the

remaining bolts being identified based on their position in relation to the first bolt. A 3D non-contact measuring equipment 11 is positioned centrally on a tower platform illustrated by the plane 12. The 3D non-contact measuring equipment may for example comprise a laser scanner or a camera or recorder for photo trigonometry. The 3D non-contact measuring equipment 11 is positioned to have a line of sight to the reference marks 10 of each bolt as illustrated by the dotted lines 13. When rotating (as indicated by the arrow 14), the 3D non-contact measuring equipment 11 can sweep the bolts and thereby for each bolt determine the distance (100, see figure 3) between the reference marks 10 together with the ID data 9 of the bolt.

Figure 3 illustrates a bolt 5 according to an embodiment of the invention and as positioned in a flange connection 4. The bolt 5 comprises two reference marks 10 positioned at each opposite end of the bolt 5 – here at a surface of the bolt head 6 and at the opposite threaded end 8 of the bolt. The distance 100 between the reference marks 10 may be determined as the distance in a direction parallel to the centre axis of the bolt between normal planes that intersects the reference marks 10. The bolt further comprises an identifier 9. The reference marks 10 and the identifier 9 are positioned such as to all be in the line of sight from some point distant to the bolt. Hereby the 3D non-contact measuring equipment can be positioned to have a line of sight to the reference marks and the identifier. This is illustrated in figure 4.

Some of the steps in embodiments of the measurement method are illustrated in figure 4.

In an embodiment of the method, the bolts are positioned or mounted in the flange and the nuts are torqued by hand or to a specific low torque value i.e. 1000 Nm. Then the first distance measurements are performed determining the baseline distance 100 between the reference marks 10. Hereafter the nuts are turned a pre-calculated number of degrees i.e. 90 degrees and a second measurement by the 3D non-contact measuring equipment is performed and the elongation change of each bolt is determined 401. If the elongation change for a bolt is outside a pre-defined range, the tensioning of the bolt is

adjusted accordingly. A further measurement of the elongation change can then optionally be performed to ensure the correct pre-tensioning of the bolt is obtained. Preferably, the data is stored and documented for record together with the ID-data for each of the bolts, 402.

- 5 In embodiments the ID-data may as mentioned above be a soft ID that is related to a first bolt of the flange connection.

In an embodiment of the invention, the baseline distance between the reference marks is determined for the bolts for example during assembly or at some time where the tensioning of the bolts is known. For example at a zero tension
10 corresponding to the bolt being in a relaxed state, or at the desired torque when the flange is newly assembled or the bolts newly tested to be correctly tensioned. At a later time during service for example after some months or years, the measurement can then be repeated 400 and the current distance between the reference marks determined 401, the earlier determined baseline
15 measurements extracted 403, to hereby confirm or verify that all bolts still have the required pre-tension (and corresponding elongation). Or if this is not the case, to inform the service technicians of specifically which bolts that are outside the specified tension level and therefore need to be adjusted and how. The newly measured current distance between the reference marks may then
20 optionally be logged and stored as new baseline information, 402.

While preferred embodiments of the invention have been described, it should be understood that the invention is not so limited and modifications may be made without departing from the invention. The scope of the invention is defined by the appended claims, and all devices that come within the meaning of the
25 claims, either literally or by equivalence, are intended to be embraced therein.

CLAIMS

1. A method of assembly and maintenance of a flange connection of two flanges connected by a number of bolts, the method comprising:

- providing each bolt with a reference mark at each opposite end of the bolt;

5 - measuring on each bolt a baseline distance between the reference marks at a pre-defined tensioning of the bolt;

- tensioning the bolts when positioned to connect the flanges;

- positioning a 3D non-contact measuring equipment such as to have a line of sight to the reference marks on the bolts;

10 - measuring on each bolt the distance between the reference marks by means of the 3D non-contact measuring equipment thereby obtaining a current distance on each bolt, and

- determining for each bolt an elongation change based on the difference between the current distance and the baseline distance.

15 2. A method according to claim 1, wherein the method comprises the further steps of:

- determining for each bolt a tensioning operation as a function of the elongation change of the bolt, and

20 - adjusting the tensioning of each bolt in accordance with the tensioning operation of the bolt.

3. A method according to claim 2, wherein the tensioning operation comprises tightening the bolt if the determined elongation change is below a pre-defined lower threshold.

25 4. A method according to claim 2, wherein the tensioning operation comprises loosening the bolt if the determined elongation change is above a pre-defined upper threshold.

5. A method according to claim 2, wherein the tensioning operation comprises keeping the tension of the bolt unchanged if the determined elongation change is within a pre-defined range.

6. A method according to any of claims 2-5, wherein the tension operation of a first bolt is further determined as a function of the elongation change of one or more of the other bolts in the flange connection.

7. A method according to any of the preceding claims, wherein each bolt further comprises an identifier comprising an ID of the bolt, and wherein the method further comprises for each bolt detecting and storing the ID together with the measured baseline distance.

8. A method according to any of the preceding claims wherein the pre-defined tension is zero and the bolt is in a relaxed state when measuring the baseline distance.

9. A method according to any of the preceding claims further comprising positioning the bolts in the flanges prior to the step of measuring the baseline distance and wherein the measuring of the baseline distance is performed by means of the 3D non-contact measuring equipment.

10. A method according to any of the preceding claims, wherein the current distance is measured on at least a part of the bolts prior to adjusting the tensioning of the part of the bolts.

11. A method according to any of the preceding claims, wherein the step of measuring the baseline distance is performed at a time prior to or during assembly of the flange connection and the step of measuring the current distance and adjusting the tensioning of each bolt is performed at a later time during assembly or maintenance of the flange connection.

12. A method according to any of the preceding claims, wherein the reference marks of the bolts are provided by application of paint and/or by the making of indentations.

13. A method according to any of the preceding claims, wherein the measuring of the distance between the reference marks by means of the 3D

non-contact measuring equipment comprises measuring by means of laser beam or photo trigonometry.

14. A method according to any of the preceding claims, wherein at least one of the flanges in the flange connection forms part of a tower section, a
5 foundation section, or a nacelle of a wind turbine.

15. A bolt comprising a first threaded end for receiving a nut and an opposite second end, the bolt comprising a reference mark positioned at each opposite end and wherein the reference marks are positioned such as to have a line of sight to one single point distant to the bolt.

10 16. A bolt according to claim 15, wherein the bolt further comprises an identifier comprising an ID of the bolt.

1/3

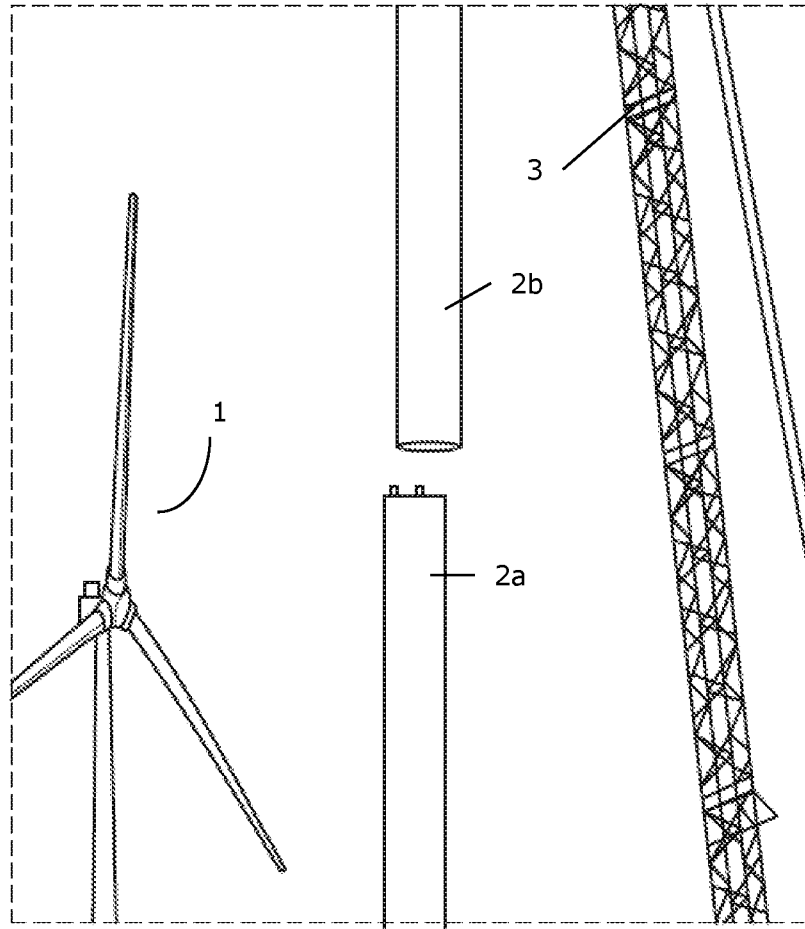


Fig. 1

2/3

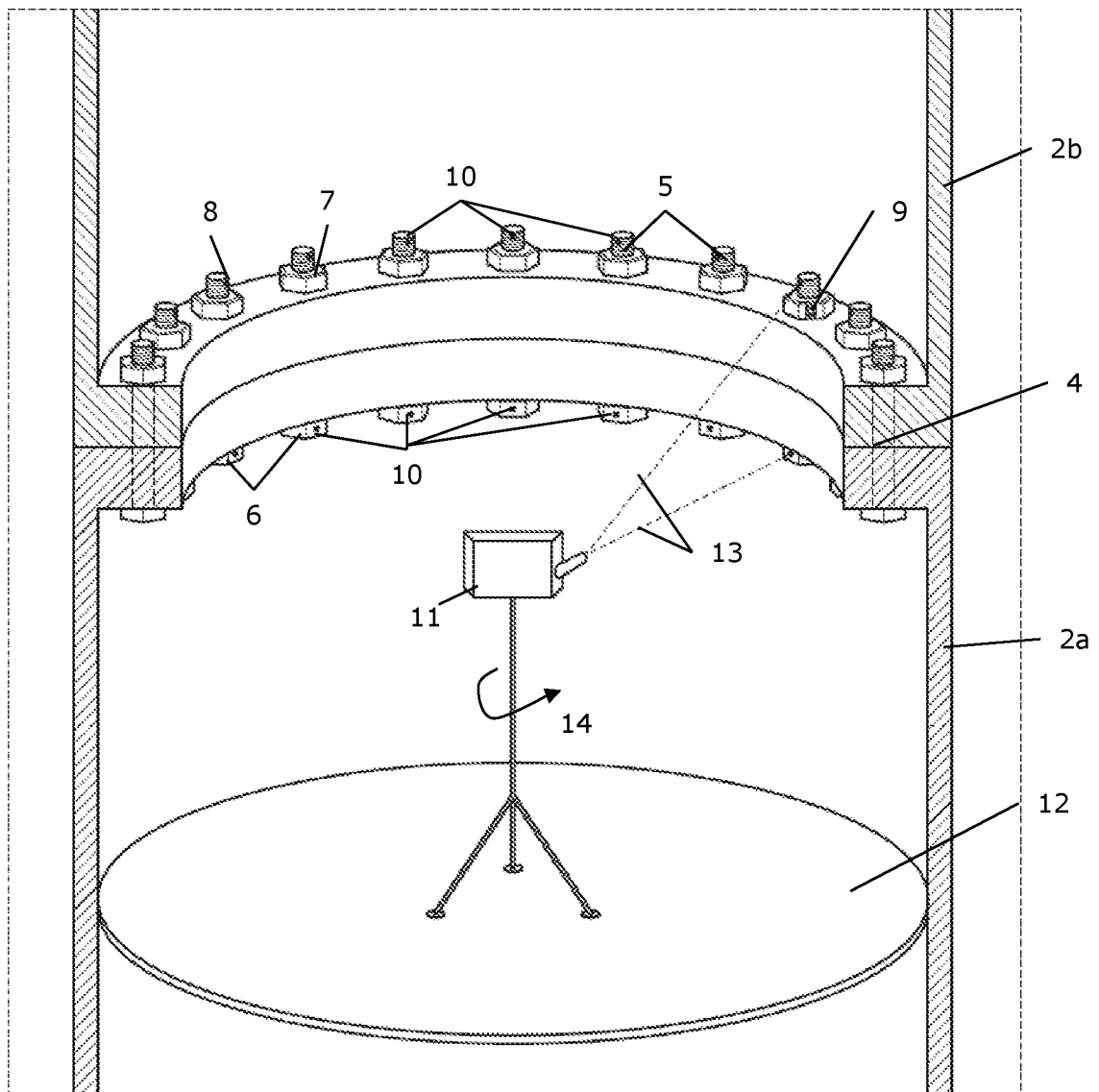


Fig. 2

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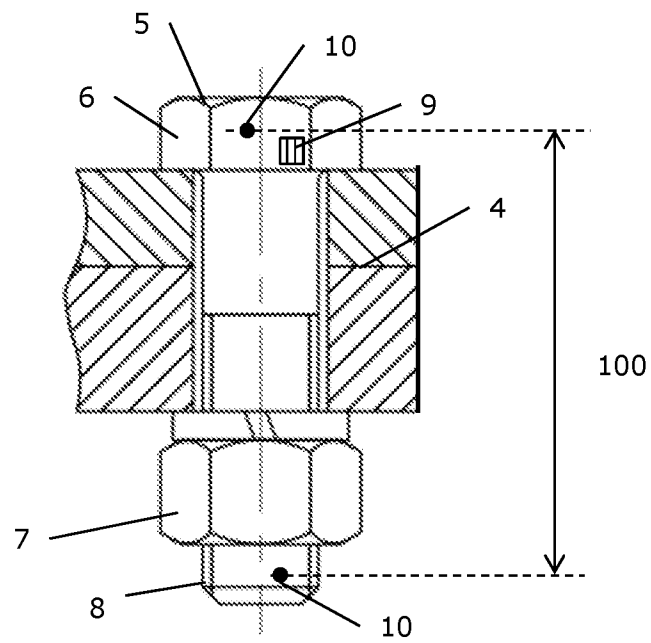


Fig. 3

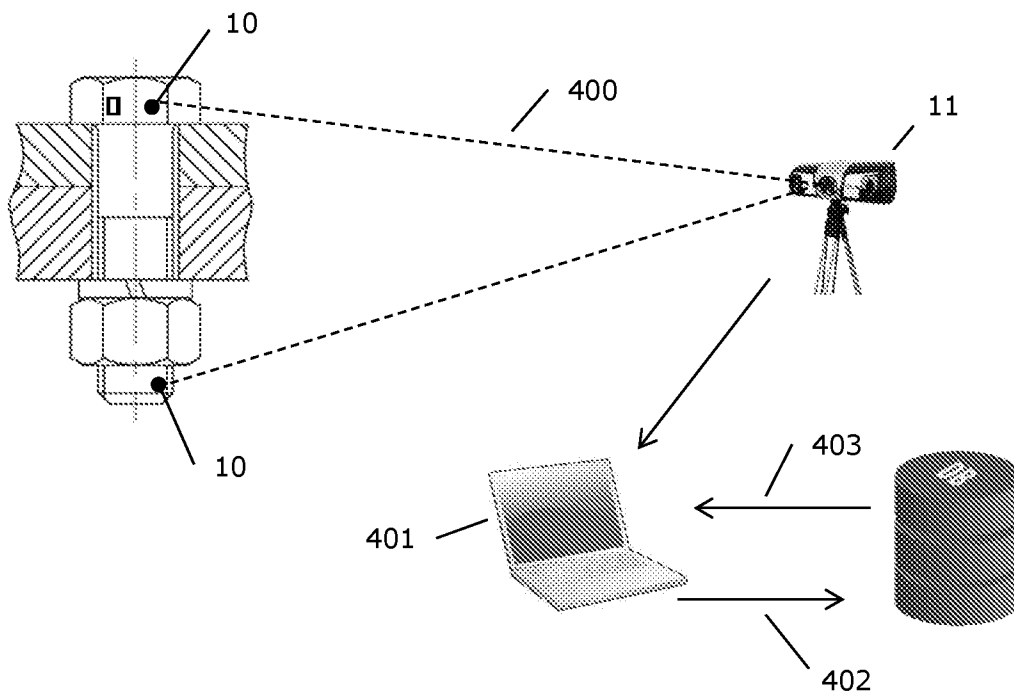


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/DK2017/050410

A. CLASSIFICATION OF SUBJECT MATTER

INV. F16B1/00 F16B31/02
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

F16B G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

15 February 2018

Date of mailing of the international search report

26/02/2018

Name and mailing address of the ISA/

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Pöll, Andreas

INTERNATIONAL SEARCH REPORT

International application No
PCT/DK2017/050410

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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