Field of invention

The present invention relates to a system for subsea, remotely operated tensioning and relaxing of mooring lines according to the preamble of claim 1, to a method for subsea, remotely operated tensioning and relaxing of mooring lines by the system, and to a connecting device and an operating device for use in the system.

Thus the present invention relates to offshore mooring systems. More specifically it relates to a subsea, remotely operated tension adjusting system for mooring lines where the lines comprise chain sections.

Relevant prior art is disclosed in WO 2013/004749 A1 which discloses the features of the preamble of claim 1.

Introduction and background

Definitions and Abbreviations

The abbreviations used in this document are:

ESD  Emergency Shut Down
MBL  Minimum Breaking Load
MLBE  Mooring Line Buoyancy Element
ROV  Remotely Operated Vehicle
STL  Submerged Turret Loading
STP  Submerged Turret Production
WROV  Work ROV

The definitions used in this document shall be understood as follows:

Buoy: Complete STL / STP Buoy comprising:
Buoyancy Cone, Bearings, Turret, ESD valves, Buoy part of Hydraulic and Signal Connectors, Riser hang-offs and connections, Mooring connections and Pick-up Assembly.
Connectin device: Chain connecting device that is permanently/fixe
located in the mooring line; also simply 'Connector'.

Operating device: Tool to operate the connecting device during tension
adjusting operation; attachable to and detachable from
the connecting device.

Tensioning system: System comprising connecting device and operating
device; also called 'tensioner'.

Mooring System: Complete mooring system comprising: Anchors, Chain,
Wire, Polyster Rope, Mooring Line Buoyancy Elements
and Connections.

Riser System: Flexible riser and umbilical system from seabed to
vessel.

Riser: Flexible riser for transfer of liquids and gases.

Subsea System: Field related system comprising: Mooring, Buoy and

Riser/umbilical System.

Umbilical: Flexible umbilical for power/hydraulic and signal lines.

Mooring systems in deep and ultradeep waters often require use of polyester
ropes, because of weight issues and vessel offset limitations. One drawback
with polyester ropes is however that it creeps over time when subject to
continuous loading. It also creeps when it experiences loads higher than it
has seen earlier. Part of this creep can be mitigated by stretching the rope to
a high tension during the offshore installation campaign, but for practical
reasons (installation vessel capabilities and safety) there is an upper limit on
how much tension that can be applied. Hence, re-tensioning of polyester
systems will most likely be required regularly over the design life of the field.

Buoys do often not have any re-tensioning possibility, because that feature
would grow the size and the complexity of the Buoy. Re-tensioning has
therefore been done as a combination of tensioning during installation (to
typically 20-30% of the MBL for the polyester rope), and by opening the line,
cutting chain and closing the line again, if later re-tensioning is required. The
latter operation may however be expensive, as it typically requires large vessel(s) with significant winch/crane capacity, ROV, weather limitations, long planning due to limited number of vessels that can do the operation, etc.

There exists thus a need for a new tensioning system in order to simplify and reduce the cost/risk of the present tension adjusting methodology.

**Summary**
The present invention, as defined in claim 1, is a mooring line tension adjusting system comprises a connecting device, connecting and locking two adjacent chain sections of a mooring line, and an operating device, moving one of the chain sections inside the connecting device to change the tension of the mooring line. The system has the inventive feature that the operating device is remotely attachable to the connecting device before a tensioning operation and detachable from the connecting device after the tensioning operation.

One of the parts comprised in the system is a connecting device, comprising a first connection arrangement for a first chain and a second connection arrangement for a second chain wherein the first connection arrangement provides a permanently fixed connection of said first chain and the second connection arrangement provides a connection which can be modified by an operating device. The connecting device comprises a first docking element - for instance a pin - enabling the operating device to firmly attach to the connecting device prior to performing a tension adjusting operation.

The second part of the system is an operating device with a second docking element being compatible with the first docking element, enabling the operating device to firmly attach to the connecting device to perform a tension adjustment operation.
A further aspect of the invention is a method for tensioning the mooring line with the tension adjusting system disclosed above. The method comprises:

a. positioning a surface vessel above the mooring line, slightly to the side of a connecting device, where two sections of the mooring line are connected by the connecting device;

b. attaching one end of a first chain or similar elongated element to one of two attachment points provided on a guide at a lower end of the operating device and attaching a first weight bar to the second end of the first chain;

c. attaching a second chain or similar element, longer than the first chain to a second attachment point on the guide at the lower end of the operating device and attaching a second weight bar to the second end of the second chain;

d. attaching a lifting/handling equipment to a third attachment point at an upper end of the operating device;

e. connecting an umbilical to a power system of the operating device, and to a power supply system on board of the surface vessel;

f. overboarding the operating device with the umbilical and accessories and lower it slightly above the same depth as the connecting device mounted into the mooring line;

g. moving the vessel such that the second chain hits the connecting device, and by moving the vessel slightly passed but without the second chain jumping over the operating device should rotate such that it orients correctly relative to the connecting device;

h. lowering the operating device such that the connecting device is between the first and the second chain;

i. continuing to lower the operating device until it sits on top of the connecting device;

j. after the lower end of the operating device has docked onto the connecting device sliding it down along the connecting device until it stops against a first docking element, a second docking element on the operating device connecting around the first docking element;
k. operating the operating device via the umbilical for pushing the mooring line in a tensioning direction; repeating this step until a requested tension is achieved;

l. lifting the operating device off the connecting device, unhooking from the first docking element.

Brief description of the drawings

Below the invention will be described in detail with reference to the attached figures. Contents of the figures as follows:

10 Figure 1 Typical mooring line composition including both rope (25) and chain parts (26). The inventive tensioning system may replace kablingselementerne (27, 28)

Figure 2 Location of the tensioning system/connector (1) in the mooring system

15 Figure 3 Assembly of the connecting device (1) and the operating device (2) of the tensioning system

Figure 4 Fixed tensioner part (1) and operating device (2) with illustration of force direction (18) from chain onto locking elements

20 Figure 5 Connecting device (1) of tensioning system

Figure 6 Operating device (2) of the tensioning system

Figure 7 Docking of operating device (2) onto connecting device (1)

Figure 8 Illustration of connecting device (1) and operating device (2) including tensioned chain (4) and free end (19)

Figure 9 Illustration of docking of operating device (2) onto connecting device (1)

Figure 10 Tensioning operation

Figure 11 Slackening operation

30 Figure 12 Mid Line Tensioning system (1, 2)

Figure 13 Mid Line Tensioner Connecting device (1)

Figure 14 Mid Line operating device (2); Removable Tool
Detailed description

Main goal of this inventive concept is to manage regular tensioning adjustments of mooring lines (30) - both tensioning and relaxing, in order to stay within the design envelope of the mooring system. The tensioning system shall not require a huge offshore campaign, and the operation shall be done with a relatively small vessel (11) in combination with an ROV, without opening the mooring line (30). The re-tensioning operation is planned conducted with a vessel with minimum crane or A-frame capacity, but equipped with an ROV/WROV that can observe the operation as well as operate the power (normally hydraulics) of the tensioning system. Alternatively, the power can be operated via an umbilical between the tensioner (2) and the vessel (11).

The inventive tensioning system comprises two main parts; confer Figure 4 for a general illustration and figures 3, 5, 6, 12 to 16 for further details:

- Connecting device (1); this component becomes a permanent/fixed part in the mooring line
- Operating device (2); this is a tool, used (only temporary) for the tensioning/slacking process, also called 'removable part'

The operating device (2) of the system can be mounted/docked on top of the connecting device through a hook (21) or similar arrangement at the lower end. During the tensioning process the pushing element (6) of the operating device (2) pushes the upper chain (4) towards the lower end of the connector (1). The movement of the chain unlocks the locking element (5) of the connecting device (1), which remains unlocked until the chain has moved far enough for the locking element (5) to drop down by gravity and thereby lock the chain (4) again. The pushing element can then be retreated such that it
can take a new grip and repeat the sequence until the mooring line has been shortened to the desired length. Each cycle will typically move two chain links.

A corresponding operation can also be used to lengthen the mooring line thus reducing the tension, but this requires that the locking elements (5) of the connecting device (1) are lifted by the ROV when the pushing element (6) has off-loaded the contact between the chain (4) and the locking elements (5). Otherwise it will lock the chain from being moved backwards.

The system will most likely be located above or below the Mooring Line Buoyancy Element (MLBE, 29), as shown in Figure 1 and Figure 2.

The reason for dividing the system into a fixed (1) and a removable part (2) is to minimize the permanent weight in the mooring system and thereby minimize the required buoyancy of the MLBE and the STL/STP Buoy. It will also reduce the overall cost since the same removable part can be used for all mooring lines, and maintenance of the hydraulic parts and the mechanical components may be easier.

A fixed weight for instance a hinged rod (8) is attached to the connecting device in order to lower the overall centre of gravity and thus ensure that the connecting device (1) is always upright. This weight may not be required.

The locking elements (5) for the chain can be kept in place by plates on each side as well as a one-sided bolt with threads on one side and threadless and headless on the other side. This bolt is entered through the outer tensioner wall into the locking element and locked inside the element.

When the bolt is fully fixed it is flush with the outer tensioner wall and free to rotate inside the hole in the wall. There is clearance between the wall
opening and the bolt such that the load from the chain into the locking element and further into the support structure does not stress the bolt.

Hydraulically operated cylinders (7) f. inst can be mounted on the operating device (2), preferably one on each side of the tool, in order to provide the required force to push the chain (4). Total available force from two hydraulic cylinders could be 150 tonnes, which means that each unit would have to provide minimum 75 tonnes. The cylinder units will be connected together such that they provide the same push at the same time. Hydraulic pressure could be provided via a WROV or directly via an umbilical (14) from the surface.

The tension adjusting system can be protected against corrosion in order to avoid any degradation of the functionality due to the marine environment. However, since the operating device (2) typical is only used temporarily, this protection needs only be considered to be applied to the connecting device (1).

Operation procedure

The following provides a possible high level description of the tensioning operation. The main steps in the tensioning operation would be, see also Figures 7, 8, 9, 10 and 11:

1) Position a surface vessel (11) above the mooring line, slightly to the side of the connecting device (1).
2) Attach a chain (23) or similar to one of the padeyes on the V-shaped guide (10) at the end of the operating device (2). Attach a weight bar (22) to the end of the chain (23).
3) Attach a longer chain (16) or similar to the other padeye on the V-shaped guide (10) at the end of the operating device (2). Attach a weight bar (15) to the end of the chain (16).
4) Attach a lifting/handling wire (13) to the padeye at the upper end of the operating device (2).

5) Connect the (typically hydraulic) umbilical (14) to the power system (7) of the operating device (2), and to power providing unit on board the surface vessel (11).

6) Overboard the operating device (2) with the umbilical (14) and the chain accessories (16, 23) and weight bars (15, 22) and lower it to almost the same depth as the connecting device (1) mounted on the mooring line. Pay out the umbilical (14) accordingly. The operating device (2) should now be positioned slightly to the side (the side depends on which side of the operating device (2) the longer chain (16) is connected) of the connecting device (1), with the lower end of the weight bar (22) connected to the short chain (23) above the connecting device (1) and the other bar (15) below the connecting device (1).

7) Move the vessel (11) such that the longer chain (16) hits the connecting device (1). By moving the vessel slightly passed but without the long chain (16) jumping over the operating device (2) should rotate such that it orients correctly relative the connecting device (1).

8) Lower the operating device (2) such that the connecting device (1) is between the two chain segments (3 and 4); confer Figure 7 and Figure 9. Continue to lower it until the operating device (2) sits on top of the connecting device (1). After the lower end of the operating device (2) has docked onto the connecting device (1) it will slide down the connecting device (1) until it stops against the pin (20), which the hook (21) shall connect to. Continue to pay out until the operating device (2) has fully docked, and the hook (21) is fully engaged around the pin (20). The hook (21) will connect to the pin (20) at a relative angle of 30 to 45 degrees between the fixed device (1) and operating device (2); 0 degrees is when they are fully latched together.

9) With the supervision of an ROV, operate the hydraulic units (7) via the umbilical (14) to the surface vessel (11) for the pushing the chain. Number of cycles of 2-link pushes depends on how much total length
adjustment that is required, confer the pushing sequence shown in Figure 10.

10) When the tensioning has been completed the operating device (2) is lifted off the connecting device (1), and either lifted onboard the surface vessel (11) or moved to the next mooring line.

For slackening the system, the same procedure can be used, but the cylinder pistons (7) are operated in the opposite direction, confer Figure 11. Another difference is that when the pushing segment release the stresses on the locking elements (5) by pushing at the far end of the 2-link grip the locking elements (5) on the connecting device (1) must be lifted/opened by the ROV; otherwise the locking elements (5) will prevent the chain (4) from being moved backwards. The ROV will let the locking elements engage with the mooring chain as soon as the first link has passed underneath the element (5).
1. System til undersøisk, fjernstyret stramning og slækning af fortøjningsliner omfattende:

en forbindelsesindretning (1) til permanent forbindelse af to tilstødende kædeafsnit (3,4) af en fortøjningsline (30) i en ønsket længde, hvor et tilstødende kædeafsnit er en kæde, hvilken bliver holdt i et led af en låseindretning (6), k e n d e t e g n e t v e d

een betjeningsindretning (2) der kan fjernforbindes til forbindelsesindretningen, for at stramme eller slække spændingen i fortøjningslinen ved at stille på længden af fortøjningslinen, ved at bevæge kæden og ændre forbindelsen indeni forbindelsesindretningen,

hvor systemet omfatter en stift (20) af forbindelsesindretningen og en krog (21) af betjeningsindretningen ved en nedre ende, hvor krogen er indrettet til at gå i indgreb rundt om stiften, for at forbinde betjeningsindretningen til forbindelsesindretningen.

2. Fremgangsmåde til undersøisk, fjernstyret stramning og slækning af fortøjningsliner ved hjælp af systemet ifølge krav 1, k e n d e t e g n e t v e d de følgende trin:

   a. at anbringe en betjeningsindretning (2) ovenpå en forbindelsesindretning (1);
   b. at låse betjeningsindretningen fast til forbindelsesindretningen ved hjælp af en stift og en krog, der går i indgreb rundt om stiften;
   c. at styre forbindelsesindretningen ved hjælp af betjeningsindretningen for at stramme eller slække fortøjningslinen, ved hjælp af kædeafsnittet, indtil den ønskede spænding opnås;
   d. at frigøre og fjerne betjeningsindretningen fra forbindelsesindretningen.

3. Fremgangsmåde ifølge krav 2, hvor det at anbringe betjeningsindretningen ovenpå forbindelsesindretningen omfatter følgende trin:

   a. at fastgøre en ende af et kort, aflangt element (23) til ét af to fastgørelsespunkter, tilvejebragt på en føring ved en nedre ende af betjeningsindretningen (2);
b. at fastgøre en ende af et længere, aflangt element (16), hvilket er længere end det korte, aflange element, til et andet fastgørelsespunkt på føringen ved den nedre ende af betjeningsindretningen;

c. at fastgøre løfte-/håndteringsudstyr (13) til et tredje fastgørelsespunkt ved en øvre ende af betjeningsindretningen (2), og at sænke betjeningsindretningen ned indtil det korte, aflange element er placeret over og det længere, aflange element, i det væsentlige i forhold til dybde, overlapper forbindelsesindretningen (1) anbragt i fortejningslinen;

d. at bevæge betjeningsindretningen sideværs indtil det længere, aflange element (16) rammer forbindelsesindretningen, og betjeningsindretningen roterer så det korte, aflange element hænger på den modsatte side af forbindelsesindretningen, set ud fra det længere, aflange element (16);

e. at sænke betjeningsindretningen ned på forbindelsesindretningen, med det korte og det længere aflange element på hver sin side af forbindelsesindretningen.

4. Fremgangsmåde ifølge krav 3, hvor mindst ét af det korte og det længere aflange element (23,16) er en kæde.

5. Fremgangsmåde ifølge krav 2, hvor det at låse betjeningsindretningen (2) til forbindelsesindretningen (1) omfatter

   a. at sænke betjeningsindretningen i lodret orientering, ned på den ikke lodrette, i en fortejningsline monterede forbindelsesindretning;

   b. at bevæge betjeningsindretningen langs forbindelsesindretningen indtil krogen (21) går i indgreb rundt om stiften (20); og

   c. at ændre orienteringen af betjeningsindretningen fra lodret til at være parallel med forbindelsesindretningen, for at låse krogen fast om stiften.

6. Fremgangsmåde ifølge krav 2, hvor frigørelsen af betjeningsindretning (2) fra forbindelsesindretningen omfatter

   a. at ændre orienteringen af betjeningsindretningen (2) fra at være
parallel med forbindelsesindretningen til at være lodret, for at frigive løsningen af krogen rundt om stiften;

b. at bevæge betjeningsindretningen langs forbindelsesindretningen indtil krogen ikke længere er i indgreb rundt om stiften, og
c. at fjerne betjeningsindretningen fra forbindelsesindretningen.

7. Fremgangsmåde ifølge krav 2, hvor længden af fortøjningsslinen bliver justeret ved
   a. at overtage en spændkraft i kædeafsnittet med betjeningsindretningen;
   b. at frigøre laseindretningen (6) fra kædeafsnittet;
   c. at bevæge kædeafsnittet i stramnings- eller slækningsretning med betjeningsindretningen;
   d. at overføre spændkraften i kædeafsnittet tilbage til laseindretningen (6).

8. Fremgangsmåde ifølge krav 2, hvor betjeningsindretningen betjenes via et forsyningskabel.

9. Fremgangsmåde ifølge krav 8, hvor betjeningsindretningen er forbundet med forsyningskablet til et fartøj eller et fjernstyret undersøiskfartøj.

10. Fremgangsmåde ifølge krav 9, hvor effekt og kontrolsignaler bliver sendt igennem forsyningskablet til betjeningsindretningen.

11. Fremgangsmåde ifølge krav 10, hvor effekt omfatter hydraulisk effekt.

12. Forbindelsesindretning til brug i systemet i krav 1, k n d e t e g - n e t ved, en stift (20) af forbindelsesindretningen, hvor stiften er indrettet til, at en krog (21) på en betjeningsindretning (2) går i indgreb rundt om den for at forbinde betjeningsindretningen til forbindelsesindretningen.

13. Betjeningsindretning til brug i systemet i krav 1, k n d e t e g - n e t ved, en krog (21) af betjeningsindretningen ved den nedre ende, hvor krogen er indrettet til at gå i indgreb rundt om en stift (20) på en forbindelsesindretning (1), for at forbinde betjeningsindretningen med forbindelsesindretningen.