

A riser connector assembly

Field of the invention

The invention relates to connectors for releasably connecting riser pipes in an end-to-end relationship. More specifically, the invention concerns a connector assembly as set
5 out in the preamble of claim 1, and methods of disconnecting and connecting riser pipes as set out in the preambles of claims 9 and 11.

Background of the invention

Production of hydrocarbons from subterranean reservoirs below a seabed is well known. In such operations, a floating drilling or/and production vessel is positioned above a
10 subsea wellhead, and a riser extends between the vessel and the wellhead. Over the years, technological advances have made it possible to extract hydrocarbons from subsea reservoirs at ever increasing water depths; operations at water depths exceeding 3000 meters is not uncommon today.

A drilling riser comprises a number of successive sections (often referred to as “riser
15 joints”) whose adjacent ends are connected on board the vessel as the riser is being lowered towards the wellhead. A riser joint is typically made up of a main pipe and external auxiliary lines, all having connectors at each respective ends. The main pipe is configured for conveying drilling fluid, while auxiliary lines referred to as “kill and choke lines” are used for circulating fluids between the drilling vessel and a blow-out
20 preventer (BOP) on the subsea wellhead, in a manner which is well known in the art.

When operating in water depths around 3000 meters and beyond, the riser mass – that the floating vessel must support – is considerable. Drilling operators and oil companies are therefore always looking for means to reduce the size and weight of the riser joint components. On the other hand, as some of the auxiliary lines (notably the kill and
25 choke lines) convey fluids that are under considerable pressure, their wall thicknesses must be of a certain magnitude. It is therefore of particular interest to design the riser connector such that the loads caused by the main pipe and the auxiliary lines are transferred between the riser joints in an efficient manner, while the connector mass is optimized.

The prior art includes US 4 043 575, which discloses a connector for use between two riser pipes having a pin fitting at the end of one pipe. The pin fitting forms a portion of the connector. An end sleeve on the pin fitting has a cylindrical exterior surface and a first peripheral flange with upper and lower normal surfaces. A box fitting is at the end
5 of the other pipe and has an end box with a cylindrical inner surface engaging the cylindrical exterior surface of the pin fitting. A second peripheral flange on the box fitting has upper and lower normal surfaces and is adapted to abut the first flange. An annular nut is rotatable about the flanges and has interior threads engageable with exterior threads on a collar rotatable around the box fitting and abutting the second
10 flange. An interrupted nut flange on the nut overlies the first flange, which is also interrupted. The nut flange and the first flange can be relatively rotated to pass each other axially or to prevent such axial movement. The nut and collar can be held in any of several relatively rotated positions by a bolt and slot connection, and the collar is held by a bolt against turning on the box fitting. Both fittings carry adjustable support
15 rings for auxiliary pipes.

The prior art also includes GB 2 320 541, which discloses a riser connector having respective tubular members connected to adjacent ends of riser pipes in an end-to-end relation and having locking grooves about their adjacent ends locked by a split lock ring surrounding the adjacent ends of the tubular members. A support plate extends laterally
20 from each tubular member, mounting pipes (which may be choke and/or kill lines) to sealably interfit with one another upon movement of the tubular members into end-to-end relation. The pipes are directly locked to one another to prevent vertical separation independently of locking of the tubular members in end-to-end relation. The locking is by transverse bolts operated by levers. The lock ring is moved between locking and
25 unlocking positions by means of a cam ring having tapered conical cam surfaces thereabout for slidable engagement with follower surfaces about the lock ring.

The prior art also includes US 4 487 434, which discloses a coupling for riser pipe sections and associated parallel choke and kill line pipe sections, where one riser pipe section is inserted in a second one. One of the riser pipe sections includes a threaded
30 male end which has at least two sets of continuous threads. A female union box carried on the other riser section includes at least two sets of continuous threads interengaged

with the sets of threads on the male end, the respective sets of threads being axially and radially spaced from each other, the union box engaging the other riser pipe section for preventing the sections from moving axially relative to each other. The sections are provided with a fluid tight seal and choke and kill line sections are also penetratingly
5 joined and supported by the riser pipe sections.

The prior art also includes US 5 992 893, which discloses a riser connector wherein an upper plate is carried by an upper riser member and a lower riser plate is carried by a lower riser member of an upper connector, and upper and lower riser plates and are similarly carried by the upper and lower riser members of the second connector. The
10 plates extend outwardly from the riser members so as to support conduits connected to the ends of the auxiliary line joints which extend along the sides of the riser pipes. Thus, the lower end of an upper conduit of the upper connector is supported by the upper plate of the upper connector, while the upper end of the lower conduit thereof is supported by the plate of the upper connector.

15 The prior art also includes WO 2011/104629, which discloses a connector for assembling two riser pipe sections for offshore well drilling operations. The connector comprises a first main tube element having as an extension a male connector element provided with a male flange pierced by at least one orifice wherein an auxiliary tube element is secured, and a second main tube element having as an extension a female
20 connector element provided with a female flange pierced by at least one orifice wherein a second auxiliary tube element is secured. The male connector element fits into the female connector element so as to connect the two main tube elements and the two auxiliary tube elements. A locking ring assembles the male flange and the female flange, the locking ring being mounted mobile in rotation on the outer surface of the male flange and the locking ring cooperating with the outer surfaces of the male and
25 female flanges. The locking ring can be locked in translation by an axial shoulder provided on the male flange, and the ring can be provided with tenons that cooperate with the tenons arranged on the outer surface of the female flange.

The prior art also includes US 4 280 719, which discloses a connector having two
30 interfitting tubular elements and a locking ring with at least two staggered rows of locking lugs cooperating with corresponding locking lugs of one of the tubular

elements. The locking lugs are inscribed in cylindrical surfaces having different radii, so that when the ring is inserted on the element, its lugs slide on the lugs of the first lug row of the element to a position where the lugs of each lug row of the ring can pass between those of a corresponding row of the element to form a plurality of bayonet
5 couplings which can then be simultaneously locked.

Summary of the invention

The invention is set forth and characterized in the main claim, while the dependent claims describe other characteristics of the invention.

It is thus provided a riser connector assembly for connecting two riser sections in an
10 end-to-end relationship, each riser section comprising at least a respective main tubular element, the connector assembly comprising

- a first connector assembly portion attached to an end of the first riser section and having a plurality of first locking members;
- a second connector assembly portion attached to an end of the second riser section and
15 having a plurality of second locking members, and
- a locking device rotatably connected to the first connector assembly portion and comprising third locking members and fourth locking members

and wherein

- the first locking members and the third locking members are configured and arranged
20 to selectively and releasably interlock by relative rotation between the first connector assembly portion and the locking device;
- the second locking members and the fourth locking members are configured and arranged to selectively and releasably interlock by relative rotation between the second connector assembly portion and the locking device;

25 characterized in that

the locking device is rotatable between a first position where all said locking members are interlocked, a second position where the first locking members and the third locking members are interlocked but the second locking members and the fourth locking members not interlocked, and a third position where none of said locking members are
30 interlocked and the locking device is movable in the axial direction of the riser sections and hence removable from the first connector assembly portion.

In one embodiment, the locking device comprises a ring member, and the first locking members comprise lugs arranged on an outer peripheral surface of a male connector and the second locking members comprise lugs arranged on an outer peripheral surface of a female connector, and the third and fourth locking members comprise lugs arranged on
5 an inner surface of the locking device.

In one embodiment, each said connector assembly portion comprises at least one respective auxiliary tubular element, said tubular elements in each connector assembly portion being connected to a flange, and the first flange comprises a male connector and the second flange comprises a female connector, said male and female connectors being
10 fluidly connected to a respective main tubular element.

In one embodiment, at least one of the assembly portions comprises alignment means that are operable between a guiding state and a non-guiding state.

The at least a first alignment means is in one embodiment arranged on the rotatable locking device and configured to cooperate with at least a second alignment means on
15 the first or second flange.

The second alignment means are in one embodiment fixedly connected to its respective flange.

In one embodiment, the locking device comprises a unitary body

In one embodiment, the alignment means comprises one or more contact areas that are
20 configured for sliding contact with an external guide structure.

In the invented connector assembly, the locking ring grooves provide guiding during mating and reduces the centre-to-centre distance between the main pipe and the auxiliary lines. It is also advantageous that the non-circular flange shape optimizes weight and stiffness of the connector assembly, as only the lines that contribute to the
25 transfer of tension loads are structurally included in the connector flanges. Other lines may be attached to the flanges via hang-off brackets. The configuration of the lugs on the male and female connectors and on the locking ring allows the locking ring to be removed from the connector without having to split the locking ring. The non-circular

flange geometry, in combination with the inventive spider guide structure, provides for efficient, safe and accurate mating of successive riser joints.

The invented connector assembly and associated spider guide structure therefore provide certain benefits over the prior art in terms of reliability, HSE aspect and weight optimization. The invented connector assembly is lighter than most comparable connector assemblies using locking rings.

It is also provided a method of disconnecting two riser sections that are connected in an end-to-end relationship via respective first and second connector assembly portions, in the invented riser connector assembly, characterized by the steps of:

- a) causing relative rotation between the locking device and the first and second connector assembly portions, from said first position to said second position;
- b) removing the second connector assembly portion from the locking device;
- c) causing relative rotation between the locking device and the first connector assembly portion, from said second position to said third position; and
- d) removing the locking device from the first connector assembly portion.

In one embodiment of the above method of disconnecting, step d comprises moving the locking device in an axial direction with respect to the riser sections.

It is also provided a method of connecting two riser sections in an end-to-end relationship via respective first and second connector assembly portions, in the invented riser connector assembly, characterized by the steps of:

- a) Entering the locking device onto the first connector assembly portion by relative axial movement between the locking device and the first connector assembly portion when the locking device is in said third position;
- b) causing relative rotation between the locking device and the first connector assembly portion, from said third position to said second position;
- c) entering the second connector assembly portion at least partially into the locking device, and
- d) causing relative rotation between the locking device and at least the second connector assembly portion, from second position to said first position.

In one embodiment of the method of disconnecting or of the method of connecting, the relative rotation is caused by rotating the locking device.

Brief description of the drawings

These and other characteristics of the invention will become clear from the following
5 description of a preferential form of embodiment, given as a non-restrictive example, with reference to the attached schematic drawings, wherein:

Figure 1 is schematic illustration of a floating vessel suspending a tubular using a plurality of the connector assemblies according to the invention;

Figure 2 is a top view of the connector assembly illustrated in figure 3;

10 Figure 3 is a perspective view of an embodiment of the connector assembly according to the invention, illustrating the connector assembly in a connected and locked state (the full lengths of the pipes and lines of the riser joints are not shown);

Figure 4 is a perspective view of the connector assembly illustrated in figure 3, illustrating the connector assembly in a connected and unlocked state;

15 Figure 5 is a perspective view of the connector assembly illustrated in figure 3, illustrating the connector assembly in a disconnected state;

Figure 6 is a perspective view of an embodiment of the locking ring according to the invention;

20 Figure 7 is a sectional view along the section line A-A in figure 2; illustrating the connector assembly in a connected and locked state (corresponding to figure 3);

Figure 8 is a sectional view along the section line A-A in figure 2; illustrating the connector assembly in a connected and unlocked state (corresponding to figure 4);

Figure 9 is a sectional view along the section line A-A in figure 2; illustrating the connector assembly in a disconnected state (corresponding to figure 5);

25 Figure 10 is a side view of the connector assembly according to the invention in a disconnected state (similar to the illustrations of figure 5 and figure 9), but where the locking ring and one auxiliary line have been removed for illustration purposes;

Figure 11a is a schematic illustration of the male and female connectors in a connected state and shows the lugs of the locking ring in a locked state;

Figure 11b is a sectional drawing along the section line D-D in figure 11a;

Figure 11c is a sectional drawing along the section line E-E in figure 11a;

5 Figure 12a is an illustration similar to that of figure 11a, but the locking ring has been rotated to a position where the lugs of the locking ring are in an unlocked state (whereby the male and female connectors may be disconnected) but the locking ring remains connected to the male (upper) connector;

Figure 12b is a sectional drawing along the section line F-F in figure 12a;

10 Figure 12c is a sectional drawing along the section line G-G in figure 12a;

Figure 13a is an illustration similar to that of figure 12a, but the female (lower) connector element has been removed, and the locking ring has been rotated to a position where the lugs of the locking ring are not engaging the lugs of the male connector, such that the locking ring may be removed from the male connector;

15 Figure 13b is a sectional drawing along the section line H-H in figure 13a;

Figure 13c is a sectional drawing along the section line J-J in figure 13a;

Figure 14 is a perspective view of an embodiment of a riser spider according to the invention in an open state, in combination with an embodiment of the connector assembly according to the invention in a disconnected state;

20 Figure 15 is a perspective view of the riser spider illustrated in figure 14 in a closed, in combination with an embodiment of the connector assembly according to the invention in a disconnected state;

Figure 16 is a front view (in the direction of arrow B) of the riser spider and connector assembly illustrated in figure 15;

25 Figure 17 is a perspective view of a second embodiment of the connector assembly according to the invention, illustrating the connector assembly in a connected and locked state (the full lengths of the pipes and lines of the riser joints are not shown);

Figure 18 is a top view of the connector assembly illustrated in figure 17;

Figure 19 is a perspective view of the connector assembly illustrated in figure 17, illustrating the connector assembly in a disconnected state;

Figure 20 is a perspective view of the second embodiment of the locking ring
5 according to the invention which is also shown in figures 17 and 19;

Figure 21 is a side view of the second embodiment of the connector assembly according to the invention in a disconnected state (similar to the state shown on figure 19), but where the locking ring and one auxiliary line have been removed for illustration purposes;

10 Figure 22a is a schematic illustration of the second embodiment male and female connectors in a connected state and shows the lugs of the locking ring in a locked state;

Figure 22b is a sectional drawing along the section line D'-D' in figure 22a;

Figure 22c is a sectional drawing along the section line E'-E' in figure 22a;

Figure 23a is an illustration similar to that of figure 22a, but the locking ring has
15 been rotated to a position where the lugs of the locking ring are in an unlocked state (whereby the male and female connectors may be disconnected) but the locking ring remains connected to the male (upper) connector;

Figure 23b is a sectional drawing along the section line F'-F' in figure 23a;

Figure 23c is a sectional drawing along the section line G'-G' in figure 23a;

20 Figure 24a is an illustration similar to that of figure 23a, but the female (lower) connector element has been removed, and the locking ring has been rotated to a position where the upper lugs of the locking ring are located between the upper lugs of the male connector;

Figure 24b is a sectional drawing along the section line H'-H' in figure 24a and
25 illustrates how the male connector lower lugs are positioned between the locking ring upper lugs, which prevent the locking ring from being removed as the locking ring

upper lugs have a smaller internal radius than the outside radius of the male connector lower lugs;

Figure 24c is an illustration similar to that of figure 24a, but the locking ring has been lowered further such that the locking ring upper lugs are resting on the male connector lower lugs, and the locking ring intermediate lugs have been disengaged from the male connector;

Figure 24d is an illustration similar to that of figure 24c, but the locking ring has been rotated further, to a position where the locking ring upper lugs are located between the male connector lower lugs, whereby the locking ring may be removed from (or falls off) the male connector; and

Figure 24e is a sectional drawing along the section line K'-K' in figure 24d.

Detailed description of a preferential embodiment

The following description may use terms such as “horizontal”, “vertical”, “lateral”, “back and forth”, “up and down”, “upper”, “lower”, “inner”, “outer”, “forward”, “rear”, “above”, “below”, etc. These terms generally refer to the views and orientations as shown in the drawings and that are associated with a normal use of the invention. The terms are used for the reader’s convenience only and shall not be limiting. In the following description, the term “axial” shall be understood as referring to the longitudinal direction of the riser connector assembly, as indicated by the axial centreline C_L in figure 3. The term “radial” shall be understood as referring to the radial extension of the components being described, i.e. any plane perpendicular to the centreline C_L .

Figure 1 illustrates a floating drilling vessel 4 suspending a drilling riser 2 by a derrick 1. The riser 2 extends from the vessel 4, through a body of water V, and connects to a wellhead 3, normally comprising a blow-out preventer (BOP; not shown). The riser thus forms a conduit between the vessel 4 and a well W, which in turn connects with a reservoir R. The riser 2 is made up by a number of successive sections 5 (often referred to as “riser joints”) whose adjacent ends are connected on board the vessel as the riser is being lowered towards the wellhead. Each riser joint 5 comprises a main pipe 7 and external auxiliary lines 8, 9. The riser joints are connected in an end-to-end relationship

by connector assemblies 6. The main pipe 7 is configured for conveying drilling fluids and well fluids, while the auxiliary lines 8, 9 in the illustrated embodiment are so-called “kill and choke lines”, respectively. Other auxiliary lines (not shown in figure 1), such as hydraulic lines or booster lines, are also normally connected to the riser joint. Kill
5 and choke lines generally differ from other auxiliary lines because they need to withstand high internal pressures and are consequently designed with relatively thick walls. The wall thicknesses of e.g. the booster line and the hydraulic line, on the other hand, need not be particularly large, as these lines are designed to be operated under comparably lower pressures.

10 Each riser joint may conveniently be provided with one or more buoyancy modules (not shown).

A first embodiment of the riser connector assembly will now be described with reference to figures 2 to 13c.

Referring now to figure 5, which illustrates a connector assembly in a disconnected
15 state, the connector assembly 6 comprises an upper assembly portion 6a, a lower assembly portion 6b, and a locking ring 11. The upper assembly portion 6a forms the lower end of a riser joint 5a and the lower assembly portion 6b forms the upper end of a riser joint 5b (arranged as illustrated in figure 1). It should be understood that the full lengths of the pipes and lines of the riser joints are not shown in figure 5, but only the
20 portions being attached to the connector assembly. The locking ring 11 is rotatably and removably attached to the upper assembly portion 6a in a manner which will be described below.

The upper assembly portion 6a comprises an upper flange 10a to which is connected an upper main pipe 7a, an upper kill line 8a and an upper choke line 9a. An upper booster
25 line 12a is also connected to the upper flange, via an external hang-off bracket 13a. The upper flange 10a also comprises through-going bores 14a that may be used for other auxiliary lines (e.g. hydraulic lines; not shown). The upper kill line 8a and the upper choke line 9a extend through the upper flange to respective male connecting elements 15a, 16a, and the upper booster line 12a also terminates in a male connecting element
30 17a.

The lower connector assembly portion 6b comprises a lower flange 10b (having a shape similar to that of the upper flange 10a) to which is connected a lower main pipe 7b and lower kill and choke lines (not shown in figure 5). A lower booster line 12b is also connected to the lower flange, via an external hang-off bracket 13b. The lower flange 10b also comprises through-going bores 14b that may be used for other auxiliary lines (not shown). The lower kill and choke lines (not shown in figure 5) extend through the lower flange to respective female connecting elements 15b, 16b, and the lower booster line 12b also terminates in a female connecting element 17b. The upper and lower flanges 10a,b may be welded to, or be formed integrally with, their respective main pipes 7a,b.

The kill line, choke line and booster line are connected via the respective male and female connecting elements in a manner which is known in the art (e.g. pin/box couplings), and will therefore not be described in more detail here.

The lower main pipe 7b extends through the lower flange 10b to an annular female connector 18b, having a plurality of external lugs 19 arranged at regular intervals around the connector periphery as well as in an axial direction. The illustrated embodiment shows three circumferential rows of female connector lugs 19, the lugs within each circumferential row being arranged at regular intervals around the connector periphery.

Figure 10 shows the connector assembly in a disconnected state (similar to that of figure 5), but the locking ring and the booster line have been removed in this figure, thereby exposing an annular male connector 18a which is attached to the upper flange 10a and forming the end portion of the upper main pipe 7a. The male connector 18a comprises at its lower end a reduced diameter portion 22, designed and configured to be accommodated within the female connector 18b, and a shoulder 23a that is configured to rest against a corresponding rim 23b on the female connector 18b. The male connector 18a comprises a plurality of external lugs 20 arranged at regular intervals around the male connector periphery as well as in an axial direction. The illustrated embodiment shows two circumferential rows of male connector lugs 20, the lugs within each circumferential row arranged at regular intervals around the connector periphery. The male connector 18a also comprises a plurality of external upper lugs 21 arranged at

regular intervals around the male connector periphery. The upper and lower flanges 10a,b may be welded to, or be formed integrally with, their respective male and female connectors 18a,b.

Referring now to figure 6, the locking ring 11 comprises an upper portion 11a and a lower portion 11b, each portion being internally configured and dimensioned to receive the male and female connectors 18a,b, respectively. It is readily apparent from figure 6 that the upper portion 11a external diameter is smaller than the lower portion 11b external diameter, and that the outer surfaces of the upper and lower portions are joined by a bevelled surface portion 11c

- 10 A row of internal upper lugs 26 are arranged at regular intervals around the upper portion 11a inner periphery. A plurality of internal intermediate lugs 25 are arranged at regular intervals around the upper portion 11a inner periphery, as well as in an axial direction, below the upper lugs 26. The illustrated embodiment shows two circumferential rows of intermediate lugs 25, the lugs within each row arranged at regular intervals around the locking ring inner periphery. A plurality of internal lower lugs 24 are arranged at regular intervals around the lower portion 11b inner periphery as well as in an axial direction. The illustrated embodiment shows three circumferential rows of lower lugs 24, the lugs within each row arranged at regular intervals around the locking ring inner periphery.
- 20 The outer surface of the locking ring lower portion 11b also comprises grooves 27 that each are arranged and configured to at least partially accommodate a respective enlarged portion 15c, 16c, 17c of each female connecting element 15b, 16b, 17b when the locking ring 11 is in an unlocked position (see e.g. figure 5). The grooves 27 thus provide guiding during the mating of the upper and lower connector assemblies 6a,b.
- 25 The grooves also serve to reduce the distance between the main pipe and the auxiliary lines in each riser joint, thereby reducing the bending moments caused by loads transferred through the auxiliary lines and into the respective flange.

Referring again to figure 5, this figure illustrates a disconnected state of the connector assembly. However, the figure illustrates a state where the upper and lower connector assemblies 6a,b are quite close (e.g. immediately prior to mating or after separation),

such that the grooves 27 in fact are guiding the enlarged portions 15c, 16c, 17c of the female connecting elements 15b, 16b, 17b.

Figure 4 illustrates the connector assembly in a fully mated (connected) condition, but the locking ring 11 is in the unlocked state.

5 Figure 3 illustrates the connector assembly in a connected and locked state, where, compared to the illustration of figure 4, the locking ring 11 has been rotated counter-clockwise such that the grooves 27 are not aligned with the female connecting elements. In fact, in this position of the locking ring, the enlarged portions 15c, 16c, 17c are prevented from moving in the axial direction by the bevelled surface portion 11c.

10 Figures 7, 8 and 9 are sectional views along the section line A-A in figure 2 and correspond to the states illustrated by figures 3, 4 and 5, respectively. These figures, and in particular figure 9, illustrate how seal rings 29 are arranged in seal grooves 28 on the internal wall of the female connector 18b. The seal rings are therefore not exposed to the locking ring lugs during mating, and the risk of damaging the seals during mating is
15 reduced.

In figures 11a-c the male and female connectors 18a,b are shown in connected state and locked by locking ring lugs 24, 25, 26 (The locking ring body is not shown in the diagrammatic figures 11a, 12a, 13a, only its lugs. In the diagrammatic figures 11b,c, 12b,c, 13b,c, only lugs are shown; not the bodies to which they are connected). Figures
20 11a-c shows how the locking ring upper lugs 26 abut against respective male connector upper lugs 21, the locking ring intermediate lugs 25 abut against respective male connector lower lugs 20, and the locking ring lower lugs 24 abut against respective female connector lugs 19.

In figures 12a-c, which represent the connected-and-unlocked state, the locking ring has
25 been rotated an angle α (an arc length d_1 with respect to reference mark K on the male connector 18a) to a position where the locking ring lower lugs 24 do not abut against female connector lugs 19 but are arranged in respective spaces between adjacent female connector lugs 19 (see figure 12c). Therefore, in this state the locking ring does not support the female connector 18b, which thus may be withdrawn from the male
30 connector and the locking ring. The locking ring upper lugs 26 are still supported by

respective portions of male connector upper lugs 21, and the locking ring intermediate lugs 25 are still supported by respective portions of male connector lower lugs 20 (see figures 12a,b), whereby the locking ring still attached to the male connector.

In figures 13a-c, the female connector has been removed (as it is not supported by the locking ring, cf. figure 12c) and the locking ring has been rotated further, an angle β (an angular distance d_2 with respect to reference mark K), to a position where the locking ring upper lugs 26 are not supported by respective male connector upper lugs 21 but are arranged in respective spaces between adjacent male connector upper lugs 21, and the locking ring intermediate lugs 25 are not supported by respective male connector lower lugs 20 but are arranged in respective spaces between adjacent male connector lower lugs 20 (see figure 13b).

Figure 13b (and figures 11b, 12b) illustrates how the locking ring upper lugs 26 are arranged on a portion of the locking ring that has a greater diameter than the portion of the male connector where the male connector lower lugs 20 are arranged. Also, the locking ring intermediate lugs 25 are arranged on a portion of the locking ring that has a smaller diameter than the portion of the male connector where the upper lugs 21 are arranged. Therefore, the locking ring may be removed from the male connector without being impeded by any of the lugs on the male connector. It is apparent from figures 12a-c and 13a-c that the arc length d_2 is twice the distance d_1 and that $\beta = 2\alpha$. In one embodiment, $\beta = 45^\circ$ and $\alpha = 22.5^\circ$.

As is evident from e.g. figure 12c, the locking ring lower lugs 24 have arc lengths a_3 , that are slightly less than the arc length a_2 between adjacent female connector lugs 19 that are in the same row of lugs, such that the female connector may be removed from the locking ring when the locking ring is in the position shown in figures 12a-c.

As is evident from e.g. figure 13b, the locking ring upper and intermediate lugs 26, 25 have arc lengths a_5 , a_4 that are slightly less than the arc length a_1 between adjacent male connector lugs 20, 21 (see figure 12b) that are in the same row of lugs, such that the locking ring may be removed from the male connector when the locking ring is in the position shown in figures 13a,b.

Referring to figure 7, the skilled person will understand that the axial tensions in the main pipe 7a and the kill and choke lines 8a, 9a of the upper riser joint are transferred by the connector assembly to the main pipe 7,b and the kill and choke lines 8b, 9b of the lower riser joint. The tension loads are taken in both the main pipes and the kill and
5 choke lines, utilising well known principles and techniques.

As is clearly shown in figures 2 to 5, the upper and lower flanges 10a,b have elliptical shapes, which optimizes weight and stiffness of the connector assembly. Only the lines that contribute to the transfer of tension loads (main pipe, kill and choke lines) are structurally included in the connector flanges. Other, thin-walled lines such as booster
10 lines are simply attached to the flanges via hang-off brackets.

Figures 14, 15 and 16 illustrate the invented connector assembly in use during the mating of two successive riser joints (not shown). A spider 30, which per se is known in the art, comprises movable support plates 31a,b that may be slid back and forth to selectively support (figures 15, 16) and release (figure 14) the connector assemblies 6a,b
15 (and thus the riser joints to which they are connected).

In figure 15, the lower connector assembly 6b is being supported by the spider plates 31a,b (being in the closed positions) and thus support the riser joints (not shown) underneath. An upper riser joint (not shown) having the upper connector assembly 6a at its lower end is about to be mated with the lower connector assembly 6b. Guide
20 structures 32 ensure that the connector assemblies 6a,b are aligned before the mating process commences. As shown also in figure 14, a bevelled region 34 at the upper portion of each guide structure interacts with a respective contact area 35 on the flange, thereby ensuring a preliminary alignment prior to mating, while a linear guide portion 33 ensures alignment when the connector assemblies are being mated. Thus, by virtue
25 of the non-circular shape of the flanges 10a,b and the arrangement of the contact areas 35 such that they initially abut against the bevelled region 34 and then against the linear guide portion 33, alignment of the two connector assembly portions 6a,b is ensured during the mating and connection operation.

A second embodiment of the riser connector assembly will now be described with reference to figures 17 to 24e. It should be understood that first and second embodiments are similar, except for the features described in the following.

Figure 17 and figure 18 show that the booster lines 12a,b are integrated in the respective flanges 10a', 10b' (and not – as in the first embodiment – supported by a hang-off bracket). The figures also show that the flanges 10a', 10b' do not fully enclose the choke and kill lines 8a', 8b', 9a', 9b', but each have a respective open segment 37a,b, 38a,b. This is advantageous in order to reduce overall weight and fabrication costs for the flanges.

Figure 17 also shows that the locking ring 11' has a smooth outer surface (e.g. without the alignment groove 27 shown in figure 3). It should be noted that lock pins, etc., that are generally known in the art, are not shown.

Referring to figure 19, the female connector 18b' comprises in this second embodiment three rows of spaced apart lugs 19' and a series of castellations 36a,b at the female connector upper rim. The castellations are formed by successive notches 36a and lips 36b.

Figure 20 shows the internal lugs of the locking ring 11'. It should be noted that in this second embodiment, the locking ring 11' comprises one row of upper lugs 26' and one row of intermediate lugs 25'. As will be described below (e.g. figure 21), the locking ring upper lugs 26' are configured to interact with corresponding male connector upper lugs 21', and the locking ring intermediate lugs 25' are configured to interact with corresponding male connector lower lugs 20'.

In figure 21 the locking ring has been removed in order to illustrate the lugs of the male connector 18a'. In this second embodiment, the male connector 18a' comprises one row of upper lugs 21' and one row of lower lugs 20'. The figure shows the castellations 36a,b on the female connector 18b' and how the lips 36b are dimensioned to fit between adjacent male connector lower lugs 20'. This interaction prevents radial movement between the male connector and the female connector and thus prevents twisting forces in the coupling to be taken up by the peripheral lines (e.g. choke, kill and auxiliary lines).

In figures 22a-c the male and female connectors 18a',b' are shown in connected state and locked by locking ring lugs 24', 25', 26' (The locking ring body is not shown in the diagrammatic figures 22a, 23a, 24a, 24d,c, only its lugs. In the diagrammatic figures 22b,c, 23b,c, 24b,e, only lugs are shown; not the bodies to which they are connected).

5 Figures 22a-c shows how the locking ring upper lugs 26' abut against respective male connector upper lugs 21', the locking ring intermediate lugs 25' abut against respective male connector lower lugs 20', and the locking ring lower lugs 24' abut against respective female connector lugs 19'. If one considers that, in figure 22a, the male connector is above the female connector and thus carries the weight of the riser joint to
10 which the female connector is attached, it is apparent that male connector lugs 20', 21' in fact provide support for respective locking ring intermediate and upper lugs 25', 26', and that the locking ring lower lugs 24' provide support for the female connector lugs 19'. In figure 22b, the locking ring upper lugs 26' are barely visible.

It is also apparent from figures 22b,c that in this second embodiment, each
15 circumferential row of lugs comprises six lugs circumferentially spaced around the female connector and locking ring periphery, i.e. with an angular spacing of 30°, while each row of lugs on the male connector comprises four circumferentially spaced lugs.

In figures 23a-c, which represent the connected-and-unlocked state, the locking ring has been rotated to a position where the locking ring lower lugs 24' do not abut against
20 female connector lugs 19' but are arranged in respective spaces between adjacent female connector lugs 19' (see figure 23c). Therefore, in this state the locking ring does not support the female connector 18b', which thus may be withdrawn from the male connector and the locking ring. The locking ring upper lugs 26' are still supported by respective portions of male connector upper lugs 21', and the locking ring intermediate
25 lugs 25' are still supported by respective portions of male connector lower lugs 20' (see figures 23a,b), whereby the locking ring still attached to the male connector.

In figures 24a,b, the female connector has been removed, and the locking ring has been rotated further, to a position where the locking ring upper lugs 26' are located between the male connector upper lugs 21'. Figure 24b shows in particular how the male
30 connector lower lugs 20' are positioned between the locking ring upper lugs 26', thus

preventing the locking ring from being removed. This is because the locking ring upper lugs 26' are arranged with an internal diameter r_1 which is smaller than the outer diameter r_2 of the male connector lower lugs 20'.

In figure 24c, the locking ring has been lowered (downwards in figure 24c) until the
5 locking ring upper lugs 26' are resting on the male connector lower lugs 20'. The locking ring intermediate lugs 25' are now free and disengaged from the male connector 18a.

In figures 24d and 24e, the locking ring has been rotated further, compared to the position in figure 24c. The locking ring has now been rotated to a position where the
10 locking ring upper lugs 26' are located between the male connector lower lugs 20', whereby the locking ring may be removed from the male connector. This two-step sequence for removing the locking ring from the male connector, as shown in figures 24c,d, is i.a. a safety measure in order to prevent the locking ring from accidentally falling off the male connector.

15 In both of the embodiments described above, the locking ring is connected to the male connector when the female connector has been removed. It should be understood that a reverse configuration is possible, i.e. that the locking is connected to the female connector after the male connector has been removed. It should also be understood that the invented connector assembly may be designed for either clockwise or counter
20 clockwise rotation of the locking ring, without departing from the scope of the invention.

Claims

1. A riser connector assembly (6) for connecting two riser sections (5a,b) in an end-to-end relationship, each riser section comprising at least a respective main tubular element (7a,b), the connector assembly comprising
- 5 - a first connector assembly portion (6a) attached to an end of the first riser section (5a) and having a plurality of first locking members (20, 21; 20', 21');
- a second connector assembly portion (6b) attached to an end of the second riser section (5b) and having a plurality of second locking members (19; 19'), and
- a locking device (11; 11') rotatably connected to the first connector assembly portion
10 and comprising third locking members (25, 26; 25', 26') and fourth locking members (24; 24')
and wherein
- the first locking members (20, 21; 20', 21') and the third locking members (25, 26; 25', 26') are configured and arranged to selectively and releasably interlock by relative
15 rotation between the first connector assembly portion and the locking device;
- the second locking members (19; 19') and the fourth locking members (24; 24') are configured and arranged to selectively and releasably interlock by relative rotation between the second connector assembly portion and the locking device;
- characterized in that**
- 20 the locking device (11; 11') is rotatable between
- a first position where all said locking members are interlocked,
- a second position where the first locking members (20, 21; 20', 21') and the third locking members (25, 26; 25', 26') are interlocked but the second locking members (19; 19') and the fourth locking members (24; 24') not interlocked, and
25 - a third position where none of said locking members are interlocked and the locking device is movable in the axial direction of the riser sections and hence removable from the first connector assembly portion.
2. The riser connector assembly of claim 1, wherein the locking device comprises a ring member, and the first locking members (20, 21; 20', 21') comprise lugs arranged on
30 an outer peripheral surface of a male connector (18a; 18a') and the second locking members (19; 19') comprise lugs arranged on an outer peripheral surface of a female

connector (18b; 18b'), and the third and fourth locking members (25, 26, 24; 25', 26', 24') comprise lugs arranged on an inner surface of the locking device (11; 11').

3. The riser connector assembly of any one of claims 1-2, wherein each said connector assembly portion comprises at least one respective auxiliary tubular element (8a,b, 9a,b), said tubular elements (7a,b, 8a,b, 9a,b) in each connector assembly portion being connected to a flange (10a,b), and wherein the first flange (10a) comprises a male connector (18a) and the second flange comprises a female connector (18b), said male and female connectors (18a,b) being fluidly connected to a respective main tubular element (7a,b).
- 10 4. The riser connector assembly of any one of claims 1-3, wherein at least one of the assembly portions (6a,b) comprises alignment means (27, 15a-c, 35) that are operable between a guiding state and a non-guiding state.
5. The riser connector assembly of claim 4, wherein at least a first alignment means (27) is arranged on the rotatable locking device (11) and configured to cooperate with at least a second alignment means (15a-c) on the first or second flange (10a,b).
- 15 6. The riser connector assembly of claim 5, wherein the second alignment means (15a-c) are fixedly connected to its respective flange.
7. The riser connector assembly of any one of claims 1-6, wherein the locking device (11; 11') is a unitary body.
- 20 8. The riser connector assembly of any one of claims 4-7, wherein the alignment means comprises one or more contact areas (35) that are configured for sliding contact with an external guide structure (32).
9. A method of disconnecting two riser sections (5a,b) that are connected in an end-to-end relationship via respective first and second connector assembly portions (6a,b), in the riser connector assembly (6) of any one of claims 1-8,
25 **characterized by** the steps of:
 - a) causing relative rotation between the locking device (11; 11') and the first and second connector assembly portions (6a,b), from said first position to said second position;

- b) removing the second connector assembly portion (6b) from the locking device;
- c) causing relative rotation between the locking device (11; 11') and the first connector assembly portion (6a), from said second position to said third position; and
- d) removing the locking device from the first connector assembly portion.

5 10. The method of claim 9, wherein step d comprises moving the locking device in an axial direction with respect to the riser sections.

11. A method of connecting two riser sections (5a,b) in an end-to-end relationship via respective first and second connector assembly portions (6a,b), in the riser connector assembly (6) of any one of claims 1-8,

10 **characterized by** the steps of:

- a) Entering the locking device (11; 11') onto the first connector assembly portion (6a) by relative axial movement between the locking device and the first connector assembly portion when the locking device is in said third position;
- b) causing relative rotation between the locking device and the first connector
- 15 assembly portion, from said third position to said second position;
- c) entering a the second connector assembly portion (6b) at least partially into the locking device, and
- d) causing relative rotation between the locking device and at least the second connector assembly portion (6b), from second position to said first position.

20 12. The method of any one of claims 9-11, wherein the relative rotation is caused by rotating the locking device.