CLAIMS

1. A tensioner (11) for maintaining a tensile force in a riser (13) having an axis (39) and extending from a subsea wellhead assembly through an opening (15) in a floating platform deck (17), the tensioner (11) comprising:

a tensioner ring (21) adapted to be coupled to the riser (13);

a plurality of hydro-pneumatic cylinder assemblies (19), each having a flexible coupler (37, 41) on at least one end (33, 35) for coupling the cylinder assemblies (19) between the deck (15) and the tensioner ring (21);

wherein each flexible coupler (37,41) comprises:

a lower member (43, 81) coupled to one of the cylinder assemblies (19);

an intermediate member (53, 83) pivotally coupled to the lower member (43, 81) by a first pin (69, 91); and

an upper member (59, 85) pivotally coupled to the intermediate member (53, 83) by a second pin (67, 109), the first pin (69, 91) and the second pin (67, 109) spaced apart and perpendicular to each other so that the upper member (59, 83) may pivot on the second pin (67, 109) relative to the intermediate member (53, 83) and the lower member (43, 81) may pivot on the first pin (69, 91) relative to the intermediate member (53, 83).

2. The tensioner of Claim 1, wherein

the lower member (43) comprises a post (47) extending along an axis (39) of the cylinder assembly (19);

the intermediate member (53) comprises an inner sleeve disposed around and pivotally coupled to the post (47) to form a post annulus between the post (47) and the inner sleeve (53); and

the upper member (59) comprises an outer sleeve defining a cavity into which the post (47) and inner sleeve (53) are inserted so that an outer annulus is formed between the inner sleeve (53) and the outer sleeve (59).

3. The tensioner of Claim 1, wherein

the lower member comprises a cylinder adapter (81) coupled to an end of the cylinder assembly (19) and having two posts (87) extending from the cylinder adapter (81) opposite the cylinder assembly;

the intermediate member comprises an inner pivot (83) positioned between the posts (87) of the cylinder adapter (81), the first pin (91) passing through upper ends of the posts (87) and an upper end of the inner pivot (83); and

the upper member comprises an adapter latch assembly (85) having two prongs (101) extending from a base member (103) and a protrusion (105) extending from the base member (85) opposite the prongs (101), the second pin (109) passing through ends of the prongs (101) opposite the base member (103) and a lower portion of the inner pivot (83).

4. The tensioner of Claim 3, wherein the cylinder adapter (81) further comprises:

a circular plate, the posts (87) extending from peripheral portions of the plate opposite the cylinder assembly; and

the posts (87) having contoured ends (89) configured to receive a portion of the first pin (91).

5. The tensioner of Claim 3, wherein the inner pivot (83) comprises:

a body having a first pin bore (95) passing through the upper portion and a second pin bore (99) passing through a lower portion, the first pin bore (95) and the second pin bore (99) being perpendicular to each other; and

support members (113) extending from an outer surface of the body proximate to the second pin bore (99), the support members (113) extending in a plane parallel to an axis of the second bin bore (99), the support members (113) configured to receive a portion of the second pin (109).

6. The tensioner of Claim 3, wherein the adapter latch further comprises:

the prongs (101) having contoured openings (111) configured to receive a portion of the second pin (109).

7. The tensioner of Claim 3, further comprising anti-rotation keys (115) configured to engage at least one of the first pin (91) and the second pin (109) to prevent rotation of the first pin and the second pin relative to the posts (87) and the prongs (101), respectively.

8. A method applying tension to a riser (13) extending through a deck (17) of a floating offshore platform, the method comprising:

(a) mounting a tensioner assembly (11) having a plurality of hydro-pneumatic cylinder assemblies (19) between the deck (15) and the riser (13);

(b) providing an articulated coupling (37, 41) at an end of each cylinder assembly (19), the articulated coupling (37) having a lower member (43, 81) mounted to the end of the cylinder assembly, an intermediate member (53, 83) pivotally coupled to the lower member (43, 81) by a first pin (69, 91), and an upper member (59, 85) pivotally coupled to the intermediate member (53, 83) by a second pin (67, 109), the first pin (69, 91) and the second pin (67, 109) being spaced apart from and perpendicular to each other;

(c) in response to relative motion between the riser (13) and the platform, pivoting each of the cylinder assemblies (37) about the first pin (69, 91) and the second pin (67, 109).

9. The method of Claim 8, further comprising connecting the upper member (59, 85) to the riser (13).

10. The method of Claim 8, further comprising providing an articulated coupling (37, 41) for each of the ends of each of the cylinder assemblies (19).

CLAIMS

1. A tensioner for maintaining a tensile force in a riser having an axis and extending from a subsea wellhead assembly through an opening in a floating platform deck, the tensioner comprising:

a tensioner ring adapted to be coupled to the riser;

a plurality of hydro-pneumatic cylinder assemblies, each having a flexible coupler on each end for coupling each of the cylinder assemblies between the deck and the tensioner ring;

wherein the flexible coupler on at least one of the ends of each of the cylinder assemblies comprises

a cylinder end member coupled to one of the ends of one of the cylinder assemblies;

an intermediate member pivotally coupled to the cylinder end member by a first pin; and

an adapter selectively mountable to the deck or to the tensioner ring and pivotally coupled to the intermediate member by a second pin, the first pin and the second pin spaced apart and perpendicular to each other so that the adapter may pivot on the second pin relative to the intermediate member and the cylinder end member may pivot on the first pin relative to the intermediate member.

2. The tensioner of claim 1, wherein

the cylinder end member of each of the flexible couplers comprises a post extending along an axis of said one of the cylinder assemblies;

the intermediate member of each of the flexible couplers comprises an inner sleeve disposed around and pivotally coupled to the post by the first pin to form a post annulus between the post and the inner sleeve; and

the adapter of each of the flexible couplers comprises an outer sleeve defining a cavity into which the post and inner sleeve are inserted so that an outer annulus is formed between the inner sleeve and the outer sleeve, the outer sleeve being pivotally coupled to the inner sleeve by the second pin.

3. The tensioner of claim 1, wherein

the cylinder end member of each of the flexible couplers comprises two posts extending from the cylinder end member opposite the cylinder assembly;

the intermediate member of each of the flexible couplers comprises an inner pivot positioned between the posts of the cylinder end member, the first pin passing through the posts and the inner pivot; and

the adapter of each of the flexible couplers comprises two prongs extending from a base member and a protrusion extending from the base member opposite the prongs, the second pin passing through the prongs and the inner pivot.

4. A tensioner for maintaining a tensile force in a riser having an axis and extending from a subsea wellhead assembly through an opening in a floating platform deck, the tensioner comprising:

a tensioner ring adapted to be coupled to the riser;

a plurality of hydro-pneumatic cylinder assemblies, each having a flexible coupler on each end for coupling each of the cylinder assemblies between the deck and the tensioner ring;

wherein each flexible coupler comprises

a post extending along an axis of one of the cylinder assemblies;

an inner sleeve disposed around and pivotally coupled to the post to form a post annulus between the post and the inner sleeve;

an outer sleeve defining a cavity into which the post and the inner sleeve are inserted so that an outer annulus is formed between the inner sleeve and the outer sleeve;

the outer sleeve being pivotally coupled to the inner sleeve so that outer sleeve may pivot relative to the inner sleeve; and

the inner sleeve being pivotally coupled to the post so that the inner sleeve may pivot relative to the post.

5. The tensioner of claim 4, wherein:

the post of each of the flexible couplers has a post tensioner ring bore passing through the post, the post tensioner ring bore having an axis perpendicular to the axis of said one the cylinder assemblies;

the inner sleeve of each of the flexible couples has a sleeve tensioner ring bore passing through the inner sleeve, the post tensioner ring bore and the sleeve tensioner ring bore being coaxial; and wherein each of the flexible couplers comprises:

a tensioner pin having diameter substantially equivalent to a diameter of the sleeve tensioner ring bore and the post tensioner ring bore, the tensioner pin passing through the post

tensioner ring bore and the sleeve tensioner ring bore so that the inner sleeve may pivot on the tensioner pin relative to the post.

6. The tensioner of claim 4, wherein:

the post of each of the flexible couplings has a post cylinder bore passing through the post, the post cylinder bore having an axis perpendicular to the axis of said one of the cylinder assemblies;

the inner sleeve of each of the flexible couplings has a sleeve cylinder bore passing through the inner sleeve, the post cylinder bore and the sleeve cylinder bore being coaxial;

the outer sleeve of each of the flexible couplings has a coupler cylinder bore passing through the outer sleeve, the coupler cylinder bore being coaxial with the post cylinder bore and the sleeve cylinder bore; and wherein each of the flexible couplers comprises:

a cylinder pin having a diameter substantially equivalent to a diameter of the coupler cylinder bore and the sleeve cylinder bore, the cylinder pin passed through the post cylinder bore, the sleeve cylinder bore, and the coupler cylinder bore so that the outer sleeve may pivot on the cylinder pin.

7. The tensioner of claim 4, wherein:

the post has a post tensioner ring bore passing through the post and a post cylinder bore passing through the post, the post tensioner ring bore having an axis that is perpendicular to an axis of the post cylinder bore;

the inner sleeve has a sleeve tensioner ring bore passing through the sleeve and a sleeve cylinder bore passing through the sleeve, the post tensioner ring bore and the sleeve tensioner ring bore being coaxial, and the post cylinder bore and the sleeve cylinder bore being coaxial;

the outer sleeve has a coupler cylinder bore passing through the outer sleeve, the coupler cylinder bore being coaxial with the sleeve cylinder bore and the post tensioner ring bore; wherein each of the flexible couplers further comprises:

a tensioner pin having a diameter substantially equivalent to a diameter of the sleeve tensioner ring bore and the post tensioner ring bore, the tensioner pin passing through the post tensioner ring bore and the sleeve tensioner ring bore so that the inner sleeve may pivot on the tensioner pin relative to the post; and

a cylinder pin having a diameter substantially equivalent to a diameter of the coupler cylinder bore and the sleeve cylinder bore, the cylinder pin passing through the post cylinder bore, the sleeve cylinder bore, and the coupler cylinder bore so that the outer sleeve may pivot on the cylinder pin.

8. The tensioner of claim 7, wherein the post cylinder bore has a first diameter at a medial portion of the post cylinder bore and a second diameter at distal ends of the post cylinder bore, the post cylinder bore having a conical surface extending from the medial portion to each distal end.

9. The tensioner of claim 8, wherein the cylinder pin is configured to pivot at an angle to the axis of the post cylinder bore.

10. The tensioner of claim 4, wherein the outer sleeve has a conical recess formed in an inner diameter herein, the conical recess receiving a portion of the inner sleeve when the outer sleeve pivots relative to the inner sleeve.

11. The tensioner of claim 4, wherein the outer sleeve comprises:

a cylindrical member having an open end and a closed end, the open end proximate to one of the cylinder assemblies when the outer sleeve is coupled to the inner sleeve and the post; and

a boss coupled to an exterior surface of the closed end, the boss configured to couple to the tensioner ring.

12. A tensioner for maintaining a tensile force in a riser having an axis and extending from a subsea wellhead assembly through an opening in a floating platform deck, the tensioner comprising:

a tensioner ring adapted to be coupled to the riser;

a plurality of hydro-pneumatic cylinder assemblies, each of the cylinder assemblies having a flexible coupler on each end for coupling the cylinder assemblies between the deck and the tensioner ring;

wherein the flexible coupler on at least one of the ends of each of the cylinder assemblies comprises

a cylinder adapter coupled to one of the ends of one of the cylinder assemblies and having two lugs extending from the cylinder adapter opposite said one of the cylinder assemblies;

an inner pivot positioned between the lugs of the cylinder adapter;

a first pin passing through the lugs and the inner pivot;

an adapter latch assembly having two prongs extending from a base member and a protrusion extending from the base member opposite the prongs, the adapter latch assembly adapted to be mounted selected to the deck or the tensioner ring;

a second pin passing through the prongs; and

wherein the first pin and the second pin are spaced apart and perpendicular to each other so that the cylinder adapter may pivot on the first pin relative to the inner pivot and the adapter latch assembly may pivot on the second pin relative to the inner pivot.

13. The tensioner of claim 12, wherein the cylinder adapter further comprises:

a circular plate, the posts extending outward from peripheral portions of the plate opposite said one of the cylinder assemblies; and

the posts having contoured ends configured to receive a portion of the first pin.

14. The tensioner of claim 12, wherein the inner pivot comprises:

a body having a first pin bore passing therethrough and a second pin bore passing therethrough, the first pin bore and the second pin bore being perpendicular to each other; and

first pin bore support members extending outward relative to an axis of the first pin bore from an outer surface of the body proximate to the first pin bore, and second pin bore support members extending outward relative to an axis of the second pin bore from an outer surface of the body proximate to the second pin bore, the first pin bore support members having curved, contoured surfaces to receive a portion of the first pin, and the second pin bore support members having curved contoured surfaces to receive a portion of the second pin.

15. The tensioner of claim 12, wherein:

the prongs have curved, contoured ends and openings configured to receive a portion of the second pin.

16. The tensioner of claim 12, further comprising anti-rotation keys engaging at least one of the first pin and the second pin to prevent rotation of the first pin and the second pin relative to the posts and the prongs, respectively.

17. A method applying tension to a riser extending through a deck of a floating offshore platform, the method comprising:

a. mounting a tensioner assembly having a plurality of hydro-pneumatic cylinder assemblies between the deck and the riser;

b. providing an articulated coupling at each end of each of the cylinder assemblies, at least one of the articulated couplings on each of the cylinder assemblies having a cylinder end member mounted to one of the ends of one of the cylinder assemblies, an intermediate member pivotally coupled to the cylinder end member by a first pin, and an adapter member pivotally coupled to the intermediate member by a second pin, the first pin and the second pin being spaced apart from and perpendicular to each other, and mounting the adapter member selectively to the riser or the deck; and

c. in response to relative motion between the riser and the platform, pivoting each of the cylinder assemblies about the first pin and the second pin.

18. The method of claim 17, further comprising connecting the adapter member to the riser.

19. The method of claim 17, further comprising providing an articulated coupling for both of the ends of each of the cylinder assemblies.