INTERNAL TIEBACK FOR SUBSEA WELL

Field of the Invention

This invention relates in general to subsea oil and gas well production, and in particular to a tieback connector extending from the subsea well to a platform at the surface.

Background of the Invention

Subsea wells typically have a subsea wellhead assembly at the seafloor. In some installations, a subsea production tree will be mounted on the wellhead assembly. The tree has valves connected to flowlines for controlling flow from the well. In another type of installation, a string of tieback conduit extends from the subsea wellhead assembly to a platform at the surface. A surface tree is mounted on the upper end of the tieback conduit. Some riser systems have inner and outer tieback conduits, each of which is run separately and connected by a tieback connector. The inner and outer tieback conduits make up the tieback riser in that type of system.

The inner tieback conduit is installed by connecting a tieback connector to the lower end of the conduit and lowering it into the bore of the subsea wellhead housing assembly. The tieback connector has a locking member that locks to the subsea wellhead housing or to the tapered stress joint at the bottom of the outer tieback conduit. The inner tieback connector also has a seal that seals to an internal

component of the subsea wellhead housing assembly. Typical outer tieback connectors are locked to the exterior of the subsea wellhead housing assembly. Other outer tieback connectors are locked to the interior. An internal tieback connector typically has a mandrel with a sleeve on the exterior. The mandrel is connected to the inner tieback conduit and is capable of moving between an upper running-in position and a lower landed position in the subsea wellhead housing. An actuator holds the mandrel in the upper position until the actuator lands on structure in the wellhead housing. Then, downward movement of the inner tieback conduit causes the locking member to engage an internal profile in the subsea wellhead housing assembly.

Summary of the Invention

The tieback apparatus of this invention has a sleeve and a mandrel installed within the sleeve. The mandrel is movable between an upper position and a lower position relative to the sleeve. In one mode, the movement is without rotation of the inner tieback conduit, and in another mode, the movement is caused by rotation. The mandrel has an exterior tapered portion with a set of external threads. The threads increase in diameter from a lower end to an upper end. A radially expansible load ring is carried by the sleeve. The load ring has a set of internal threads that ratchet over the external threads as the mandrel moves from the upper position to the lower position. The load ring has an external profile that mates with an internal profile of the subsea well assembly when the mandrel is in the lower

position. In the embodiment shown, the internal profile is located within the lower portion or stress joint of an external riser. The mandrel is rotatable relative to the sleeve and the load ring while in the lower position. This rotation causes the internal threads to advance upward relative to the external threads to further expand the load ring into engagement with the internal profile of the subsea well assembly. In an alternate mode of operation, all of the expansion of the load ring is caused by rotation.

In one embodiment, the internal profile of the subsea well assembly is located within a stress joint of a riser that is connected to the subsea wellhead housing. The load ring thus engages the internal profile in the riser, connecting the tieback conduit to the mandrel.

In addition to locking to the riser stress joint, optionally, the tieback connector also locks to an internal profile located within the subsea wellhead housing. A locking member is carried by the sleeve below the load ring. The mandrel has an exterior cam surface that slides downward relative to the locking member to expand it outward at the same time as the load ring is being expanded outward. Preferably, the mandrel has threads above the cam surface that mate with threads of the locking member so that when the mandrel is rotated to further expand the load ring, it also engages the locking member threads with the mandrel threads. In the preferred embodiment, the locking member comprises a plurality of dogs spaced around the sleeve.

Brief Description of the Drawings

Figure 1 is a sectional view illustrating an inner tieback connector in the landed and connected positions.

Figure 2 is a sectional view of the tieback connector of Figure 1, shown being lowered into a subsea wellhead housing.

Figure 3 is a sectional view of the tieback connector of Figure 1, shown at a lower position in the wellhead housing.

Figure 4 is a sectional view of the tieback connector of Figure 1, shown landed in the wellhead housing but prior to rotating the mandrel.

Figure 5 is an enlarged sectional view of a portion of the tieback connector, illustrating locking dogs for locking the tieback connector to the subsea wellhead housing assembly, and shown prior to engaging the internal profile.

Figure 6 is a further enlarged view of the tieback connector, illustrating the locking dogs of Figure 5 in an engaged position with the internal profile.

Figure 7 is an enlarged view of a portion of the tieback connector of Figure 1, illustrating the actuator sleeve landed on a casing hanger in the wellhead housing.

Figure 8 is a perspective view of the exterior of the tieback connector of Figure 1.

Figure 9 is a perspective view of the load ring of the tieback connector of Figure 1.

Figure 10 is a perspective view of an alternate embodiment of the inner tieback connector of Figure 1.

Detailed Description of the Invention

Referring to Figure 1, wellhead housing 11 is located at the seafloor at the upper end of a well. Wellhead housing 11 is a tubular member having a bore containing at least one casing hanger 13. Casing hanger 13 is secured to a string of casing that extends to a selected depth in the well. A packoff assembly 15 seals between casing hanger 13 and the bore of wellhead housing 11.

In this example, a second casing hanger 17 is landed within casing hanger 13. Casing hanger 17 is attached to a string of casing that extends to a greater depth in the well than the casing attached to casing hanger 13. A second packoff assembly 19 secures the annulus between casing hangers 13 and 17.

In this example, a lockdown member 21 lands on top of casing hanger 13 to prevent upward movement of casing hanger 13. Lockdown member 21 is a tubular member that is secured by a split lock ring 23 or a segmented dog ring to an internal groove or profile 27 formed in the bore of the wellhead housing 11. Lock ring 23 is energized or expanded to the locked position by a packoff assembly 25 that is wedged between lockdown member 21 and the bore of wellhead housing 11. Other arrangements of the structure within wellhead housing 11 are feasible, including mounting the second casing hanger on top of the first casing hanger, rather than within. Also, lockdown member 21 may be eliminated in some installations. The arrangement of this example is employed for a high pressure and high temperature well.

In this example, an external riser 29, which is an outer tieback conduit, connects to an exterior profile on wellhead housing 11 and extends upward to a surface platform. A gasket 31 seals riser 29 to the interior of wellhead housing 11. Riser 29 has an internal profile 33 that in this instance comprises a plurality of rounded, parallel grooves, but other configurations are feasible.

An inner tieback connector 35 is employed to connect a string of inner tieback conduit (not shown) to the subsea well assembly, which includes wellhead housing 11 and its internal components, as well as the lower end or stress joint of riser 29. Inner tieback connector 35 has a mandrel 37, which is an inner tubular member, that is secured to the string of conduit. Mandrel 37 has an upper external set of threads 39 that are located on a tapered or conical surface. The lower end of external threads 39 has a smaller diameter than the upper end, as shown in Figure 1. Mandrel 37 also has a set of intermediate external threads 41. Threads 41 are located on a cylindrical portion of the exterior of mandrel 37. Mandrel 37 also has a lower set of external threads 43 that are located on a cylindrical portion of mandrel 35 above a tapered or conical surface. Upper threads 39, intermediate threads 41 and lower threads 43 have preferably the same pitch. In addition, mandrel 37 has an exterior groove 45 located near its lower end.

An expandable load ring 47 is carried by mandrel 37. Load ring 47 has a set of tapered internal threads 49 that have the same taper as external threads 39. Threads 49 will mesh with external threads 39 while mandrel 37 is in the lower

position shown in Figure 1. Load ring 47 also has an external grooved profile 51 that is configured to mate with riser internal profile 33.

Referring to Figure 9, load ring 47 is preferably a collet member having serpentine slots, but it could alternately be a split C-ring. These slots include upper slots 53 that extend downward from the upper edge of load ring 47 to a point near the lower edge. Lower slots 55 extend from the lower edge upward to a point below the upper end of load ring 47. Slots 53, 55 are parallel with a central axis of load ring 47.

Referring back to Figure 1, load ring 47 is secured in this embodiment by a clamp 57 or bolted retainer pieces to a sleeve 59. Clamp 57 prevents both axial and rotational movement of load ring 47 relative to sleeve 59. Other devices may be used to connect load ring 47 with sleeve 59, as discussed below in connected with the second embodiment of Figure 10.

Sleeve 59 is mounted to mandrel 37 so that mandrel 37 can move from the upper running in position shown in Figure 2 to the lower landed position shown in Figure 1. In this embodiment an internal annular recess 61 accommodates a carrier ring 63 between the annular recess 61 and the exterior of mandrel 37. Carrier ring 63 has internal threads that engage the intermediate external threads 41 on mandrel 37. Carrier 63 has a plurality of pins 65 (only one shown) on its outer diameter. Each pin 65 engages an axially extending slot 67 formed in the wall of sleeve 59. Pins 65 and slots 67 prevent carrier ring 63 from rotating relative to sleeve 59. Elongated slots 67 allow carrier ring 63 to move upward and downward relative to

sleeve 59 in unison with mandrel 37. Intermediate threads 41 allow mandrel 37 to rotate relative to sleeve 59. A shoulder at the lower end of each slot 67 prevents sleeve 59 from being accidentally detached from mandrel 37 while being run in.

Referring still to Figure 1, an actuator 69 is carried on the lower end of sleeve 59. Actuator 69 comprises a sleeve mounted to sleeve 59 below a split ring 71 that is located within an internal groove 73 in sleeve 59. Initially, split ring 71 will be in partial engagement with mandrel external groove 45 and internal groove 73, as shown in Figure 2. Referring to Figure 7, actuator 69 is urged downwardly relative to sleeve 59 by springs 75. A retainer screw 77 secures actuator 69 to sleeve 59, but allows some axial movement of actuator 69 relative to sleeve 59 because it is positioned in an axially elongated slot 79. Actuator 69 lands on structure within subsea wellhead housing assembly, and in this example, it lands on a portion of the packoff 19 between casing hangers 13 and 17. When landing, an upper end of actuator 69 cams split ring 71 outward to a fully recessed position within sleeve groove 73. Split ring 71 disengages from mandrel groove 45, allowing mandrel 37 to then move downward relative to sleeve 59.

Referring again to Figure 1, a seal 81 is carried on the lower end of mandrel 37. Preferably seal 81 is a metal-to-metal seal that seals between mandrel 37 and the inner diameter of an upper end of casing hanger 17.

A plurality of anti-rotation keys 83 will snap into engagement with a mating slot 85 formed in lockdown member 21 in this example. As shown in Figures 5, 6 and 8, keys 83 are spaced circumferentially around and extend through openings

within sleeve 59. As shown in Figure 6, each key 83 preferably is biased outward by a coil spring 87. Keys 83 are able to fully retract so that they are flush with within the exterior surface of sleeve 59.

In this embodiment, in addition to locking inner tieback connector 35 to riser 29 with load ring 47, it is also locked to an internal component of subsea wellhead housing 11. In this example, inner tieback connector 35 has a locking member comprising a plurality of dogs 89 spaced around the circumference of sleeve 59. Referring to Figures 5 and 6, each dog 89 is located within a window in sleeve 59. Each dog 89 has an external lockdown member profile 95 that partially engages an annular internal profile 91 in lockdown member 21 when fully installed. That is, the dog profiles 95 are aligned with lockdown profile 91, but a slight clearance exists between the teeth of profiles 95 and profile 91. The loose fit while in the fully installed position allows some upward movement of dogs 93 relative to profile 91.

Also, each dog 89 may have a segment of a thread or groove 93 on its interior surface. Threads 93 are located on an inner surface of each dog 89 and will mate with lower external threads or grooves 43 on mandrel 37. Threads 93 will loosely engage threads 43 and ratchet when mandrel 37 is moving downward relative to dogs 89. Dogs 89 are preferably retained within the windows of sleeve 59 by upper and lower tabs 97 (Fig. 8) or by the arrangement discussed below in connection with the embodiment of Figure 10. In this embodiment, a coil spring 99 biases each dog 89 inward to a position where its external profile 95 is flush or

recessed from the exterior surface of sleeve 59. In the arrangement of Figure 10, leaf springs are employed.

In operation, inner tieback connector 35 will be assembled as illustrated in Figure 2 and secured to a string of inner tieback conduit. Mandrel 37 will be in the upper position relative to load ring 47 and sleeve 59. Lower threads 43 will be located above dogs 89. Carrier ring 63 will be in an upper position within recess 61. Split ring 71 will be in engagement with grooves 73 and 45, which holds mandrel 37 in the upper position relative to sleeve 59. Actuator 69 will be extending below seal 81.

Figures 3 and 7 show actuator 69 landing on packoff 19. Actuator 69 pushes split ring 71 outward, freeing split ring 71 from groove 45 and allowing mandrel 37 to move downward. Sleeve 59 does not move downward because it is supported by actuator 69 on packoff 19. Load ring 47 will be aligned with riser internal profile 33, but not yet in engagement. Dogs 89 will be aligned with internal profile 91 in lockdown member 21, but not yet in engagement.

Referring to Figure 4, when the downward movement of mandrel 37 occurs, upper tapered threads 39 on mandrel 37 will ratchet downward on load ring internal threads 49, causing load ring 47 to radially expand and partially enter riser internal profile 33. The downward movement of mandrel 37 also causes dogs 89 to radially expand as they are cammed outward by cam surface below lower external threads 43. Profiles 95 on dogs 89 will partially enter lockdown member internal profile 91.

Seal 81 will move downward near the upper end of casing hanger 17, but will not yet be in sealing engagement with casing hanger 17.

The operator then rotates the inner tieback conduit, which causes mandrel 37 to rotate. Sleeve 59 may initially rotate a short increment, but its anti-rotation keys 83 will soon spring into slots 85, preventing further rotation of sleeve 59, dogs 89, and load ring 47. The rotation of mandrel 37 causes relative axial movement between mandrel 37 and load ring 47. Load ring 47 moves upward, and mandrel 37 downward into tight, preloaded engagement with riser profile 33. Threads 93 of dogs 89 engage lower threads 43 on mandrel 37 but will not make-up tightly. The remaining downward movement of mandrel 37 that occurs while it is rotating causes seal 81 to come into full sealing engagement with casing hanger 17. Afterward, the operator would run tubing, complete the well and install a surface production tree at the platform.

The completed assembly thus locks internal connector 35 both to the stress joint of riser 29 as well as to an internal component of the assembly of subsea wellhead housing 11. If riser 29 were inadvertently disconnected from wellhead housing 11, connector 35 would still remain attached to its connection with lockdown member 21 after a small amount of travel of riser 29. This connection is through the engagement of dogs 89 with profile 91 and the threaded engagement of mandrel threads 41 and dog threads 93. If mandrel 37 and sleeve 59 both began to move upward, profiles 95 of dogs 89 would come into full load bearing contact with lockdown member profile 91, preventing further upward movement. The tight

make-up of load ring 47 is not hampered by the loose engagement of dogs 89 with lockdown member profile 91.

In the first method of operation, referring to Figure 7, after actuator 69 lands on packoff 19, applying sufficient downward weight cams split ring 71 out of engagement with groove 45 and causes mandrel 37 to drop downward from the position of Figure 3 to the position of Figure 4. Referring to Figures 3 and 4, rather than applying additional weight, the operator may rotate the inner tieback conduit while in the upper position of Figure 3. This rotation causes mandrel 37 to rotate relative to load ring 47. Mandrel threads 39 engage load ring threads 49, causing mandrel 37 to move downward to the position in Figure 4. The tool can thus be operated in two different modes.

The embodiment of Figure 10 shows two changes from the first embodiment. In the first embodiment coil springs 99 (Fig. 6) urge dogs 89 inward and tabs 97 (Fig. 8) retain each dogs 89 within one of the windows in sleeve 59. In the embodiment of Figure 10, a leaf spring 101 extends across each window in contact with the outer side of each dog 89. Leaf springs 101 replace coil springs 99 (Fig. 6) and tabs 97.

The second feature that differs is to replace clamp 57 (Fig. 1), which retains load ring 47 with sleeve 59. Instead, a plurality of dovetail slots 103 are formed in the lower edge of load ring 47'. A plurality of links 105 are connected between slots 103 and sleeve 59. Each link 105 has an upper end or head that fits within one of

the dovetail slots 103. A threaded bolt or fastener 107 secures the lower end of each link 105 to the outer surface of sleeve 59.

While the invention has been shown in only two of its forms, it should be apparent to those skilled in the art that it is not so limited but susceptible to various changes without departing from the scope of the invention. For example, in some cases the locking dogs could be eliminated, with the sole connection being to the external riser. Alternately, the locking dog arrangement could be employed with another tubular members wherein another outer tubular member would take the place of lockdown member 21 and another inner tubular member would take the place of mandrel 37. Also, if an external riser is not employed, the load ring could be positioned lower and engage structure within the subsea wellhead housing.

Claims

1. An apparatus for tying back a subsea well assembly to a surface platform, comprising:

a sleeve;

a mandrel installed within the sleeve and movable between an upper position and a lower position relative to the sleeve;

a set of external threads on an exterior tapered portion of the mandrel, the threads increasing in diameter from a lower end to an upper end;

a radially expansible load ring carried by the sleeve, the load ring having a set of internal threads that engage the external threads of the mandrel, and the load ring having an external profile adapted to mate with an internal profile of the subsea well assembly; and

the mandrel being rotatable relative to the sleeve and the load ring, causing the internal threads to advance upward relative to the external threads to expand the load ring and tightly engage the external profile with the internal profile of the subsea well assembly.

2. The apparatus according to claim 1, further comprising a seal on a lower end of the mandrel for sealing against an internal component of the subsea well assembly.

3. The apparatus according to claim 1, wherein the load ring has an internal surface that is tapered and which contains the internal threads.

4. The apparatus according to claim 1, further comprising an exterior smooth tapered surface on the mandrel below the exterior tapered portion, the smooth tapered surface being engaged by the internal threads of the load ring while the mandrel is in the upper position.

5. The apparatus according to claim 1, further comprising:

at least one locking member carried by the sleeve below the load ring; and

an exterior cam surface on the mandrel below the exterior tapered portion, the cam surface being above the locking member while the mandrel is in the upper position, the locking member engaging the cam surface and expanding outward to engage a lower internal profile of the subsea well assembly while the mandrel moves to the lower position, the locking member remaining in partial engagement with the lower internal profile when the load ring is fully made up with the internal profile of the subsea well assembly.

6. The apparatus according to claim 1, further comprising:

a plurality of dogs carried within openings of the sleeve that are spaced circumferentially around the sleeve; and

an exterior cam surface on the mandrel below the exterior tapered portion, the cam surface being above the dogs while the mandrel is in the upper position, the dogs engaging the cam surface and expanding outward to partially engage a lower internal profile of the subsea well assembly while the mandrel moves to the lower

position and when the load ring is fully made up with the internal profile of the subsea well assembly.

7. The apparatus according to claim 6, further comprising:

an internal threaded segment on an inner surface of each of the dogs; and

an external set of threads on the mandrel that mates with the threaded segments.

8. The apparatus according to claim 1, wherein the internal threads of the load ring are capable of ratcheting movement as the mandrel moves downward from the upper position to the lower position.

9. The apparatus according to claim 1, further comprising:

an external groove on the mandrel that aligns with an internal groove in the sleeve while the mandrel is in the upper position;

a split ring having a locking position while the mandrel is in the upper position, wherein an outer portion of the split ring is within the external groove and an inner portion within the internal groove, thereby preventing the mandrel from moving to the lower position; and

an actuator carried by the sleeve and extending below the mandrel while the mandrel is in the upper position, the actuator having an upper end that engages the split ring and when landing on a structure within the subsea well assembly and the

application of sufficient weight, moves the split ring to a released position to allow the mandrel to move downward either with or without rotation.

10. In a subsea well apparatus having a subsea wellhead assembly and a riser extending from the subsea wellhead assembly for communicating with a surface platform, a tieback apparatus comprising:

a mandrel adapted to be secured to a string of tieback conduit extending through the riser;

a set of external threads on an exterior conical portion of the mandrel that, the threads increasing in diameter from a lower end to an upper end;

a sleeve carried by the mandrel, the mandrel being movable from an upper position during running-in to a lower position when the tieback apparatus lands in the subsea wellhead assembly;

a radially expansible load ring carried by the sleeve, the load ring having a set of internal threads that engage the external threads, and the load ring having an external grooved profile;

the mandrel being rotatable relative to the sleeve and the load ring, causing the internal threads to advance upward relative to the external threads to expand the load ring and move the internal profile into engagement with an internal profile provided in the riser, thereby locking the mandrel to the riser;

at least one locking member carried by the sleeve below the load ring; and

an exterior cam surface on the mandrel below the exterior tapered portion, the cam surface being above the locking member while the mandrel is in the upper position, the locking member engaging the cam surface and expanding outward to loosely engage a lower internal profile provided in the subsea wellhead assembly while the mandrel moves to the lower position and the load ring is fully made up with the internal profile in the riser.

11. The apparatus according to claim 10, further comprising a seal on a lower end of the mandrel that seals against an internal component of the subsea wellhead assembly.

12. The apparatus according to claim 10, further comprising an exterior smooth tapered surface on the mandrel below the exterior tapered portion, the smooth tapered surface being engaged by the internal threads of the load ring while the mandrel is in the upper position.

13. The apparatus according to claim 10, wherein said at least one locking member comprising:

a plurality of dogs carried within openings of the sleeve that are spaced circumferentially around the sleeve.

14. The apparatus according to claim 13, further comprising:

an internal threaded segment on an inner surface of each of the dogs; and

a lower set of threads on an exterior portion of the mandrel that mate with the threaded segments.

15. The apparatus according to claim 10, wherein the internal threads of the load ring are capable of ratcheting movement as the mandrel moves downward from the upper position to the lower position.

16. A method for tying back a subsea well assembly to a surface platform comprising:

(a) providing a mandrel with a set of external threads on an exterior tapered portion of the mandrel, the threads increasing in diameter from a lower end to an upper end;

(b) mounting a radially expandable load ring on the mandrel, the load ring having a set of internal threads and an external profile;

(c) connecting the mandrel to a string of tieback conduit, and lowering the mandrel and sleeve into the subsea well assembly;

(d) when the mandrel lands in the subsea well assembly, moving the mandrel downward relative to the load ring, radially expanding the load ring as the mandrel moves downward; and

(e) rotating the mandrel relative to the load ring, causing the internal threads to advance upward relative to the external threads to tightly engage the external profile with an internal profile of the subsea well assembly.

17. The method according to claim 16, further comprising:

providing an exterior cam surface on the mandrel below the exterior tapered portion;

mounting at least one locking member around the mandrel below the load ring and above the cam surface; and wherein step (d) further comprises:

expanding the locking member outward with the cam surface into partial engagement with a lower internal profile of the subsea well assembly as the mandrel moves downward such that the locking member remains in partial engagement with the lower internal profile while the load ring is tightly engaged with the internal profile of the subsea well assembly; and

fully engaging the locking member with the internal profile in the event the mandrel and the portion of the subsea well assembly containing the internal profile begin to move upward relative to the portion of the subsea well assembly containing the lower profile.

18. The method according to claim 17, further comprising:

providing a lower set of threads on the mandrel and a set of threads on the locking member, and wherein step (e) further comprises:

engaging the threads the locking member with the lower set of threads on the mandrel as the mandrel is rotated.

19. The method according to claim 16, wherein lowering the mandrel in step (c) is performed without rotation of the mandrel.

20. The method according to claim 16, wherein lowering the mandrel in step (c) is performed by rotating the mandrel.

21. A subsea wellhead assembly, comprising:

an outer tubular member having an internal grooved profile;

an inner tubular member located within the outer tubular member and having an annular cam surface located below a set of grooves;

a sleeve between the inner and outer tubular members, the sleeve having a plurality of windows;

a plurality of dogs, each dog mounted within one of the windows, each dog having an internal grooved profile and an external grooved profile;

the inner tubular member being downwardly movable relative to the sleeve and the outer tubular member from an upper position to a lower position, causing the internal grooved profiles of the dogs to engage the grooves on the inner tubular member and the cam surface to move the dogs outward so that the external grooved

profiles of the dogs loosely engage the internal grooved profile of the outer tubular member; and

wherein initial upward movement of the sleeve and the inner tubular member relative to the outer tubular member causes the external grooved profiles of the dogs to bear against the internal grooved profile of the outer tubular member, preventing additional upward movement of the sleeve and the inner tubular member.

22. The apparatus according to claim 21, wherein the external grooves on the inner tubular member comprise a set of threads, and the internal grooved profiles on the dogs comprise mating threads.

23. The apparatus according to claim 22, wherein the set of threads on the inner tubular member are located on a cylindrical portion of the tubular member.