

METAL SEALING ADJUSTABLE CASING SUB

BACKGROUND

1. Field of Invention

The device described herein relates generally to the production of oil and gas. More specifically, the device described herein relates to a sealing assembly for use in an adjustable casing sub.

2. Description of Related Art

Some offshore platforms have a production tree or trees above the sea surface on the platform. In this configuration, a casing string extends from the platform housing to a subsea wellhead housing disposed on the seafloor. Production casing inserted within the wellbore is supported on the subsea floor by a hanger in the subsea housing. The casing string between the subsea and surface wellhead housings is tensioned to prevent flexure that may be caused by thermal expansion from heated wellbore fluids or vibration from applied side loads. Additionally, the string length or height is typically adjusted to seat or land the upper casing within a surface hanger.

A sub assembly can be attached to the casing string and used to tension the casing string and adjust its length. The sub assemblies typically comprise a pair of mated housings that in response to an applied force are mechanically retractable in length. The adjustable sub assemblies connect inline within the string or on its upper end and when retracted impart a tension force on the casing string and by its retraction, shortening the casing string length.

SUMMARY OF INVENTION

According to one aspect, there is provided a tubular assembly between a platform and a subsea wellhead, the tubular assembly comprising: an adjustable casing sub coupled between the subsea

wellhead and the platform, the adjustable casing sub comprising, an outer housing, an inner housing selectively insertable within the outer housing and having a transition that defines a change in length of an outer radius of the inner housing, an annulus formed between the inner and outer housings, at least one of the housings have a seal surface in the annulus; a seal that moves from an initial position to a sealing position in the annulus adjacent the seal surface, the seal having an outer circumference with a metal face and an inner surface with cantilevered members; and a seal energizing system contained within the adjustable casing sub, so that when the seal is urged to the sealing position to where the outer radius of the inner housing is increased by the seal energizing system, the metal face is urged radially outward into sealing contact with an inner surface of the outer housing by contact of the cantilevered members with the outer radius of the inner housing.

According to another aspect, there is provided an adjustable casing sub mechanically attachable between a platform and a subsea wellhead assembly, the casing sub comprising: a first housing; a second housing, wherein the housings are telescopingly insetable within one another; an energizing sleeve provided within one of the housings; profiles formed on the energizing sleeve inner diameter for rotating the energized sleeve; a change in diameter circumscribing one of the housings, defining a transition from a clearance portion to a sealing surface on the housing; a radial annulus between the first and second housing extending across the transition; and a radial seal disposed in the annulus and axially moveable therein, the seal comprising an annular body, a cantilevered leg with an end attached to an inner circumference of the body, a metal face on an outer circumference of the body, the seal energized into sealing engagement with the sealing surface when urged past the transition from the clearance portion.

The present disclosure includes a tubular assembly extending between a platform and a subsea wellhead. In an embodiment the tubular assembly includes a casing string connected to the

subsea wellhead and an adjustable casing sub coupled between the casing string and the platform. The adjustable casing sub comprises an outer housing, an inner housing selectively insertable within the outer housing, and an annulus formed between the inner and outer housings. At least one of the housings has a seal surface in the annulus. A seal is provided that moves from an initial "clearance" position to a sealing position in the annulus adjacent the seal surface. The seal may have a metal face, the face having an interfering diameter with the seal surface causing radial deformation of the seal as it moves axially within the annulus. Also included is a seal energizing system.

The metal face may be a ductile metal and may be one of a silver coated metal, a eutectic alloy, an indium alloy, and combinations thereof. The compressive sealing surface may be a spring like element. The seal on a side opposite the metal face can include a resilient cantilevered member having a sealing surface on its free end that engages the other side of the housing. In one embodiment, the seal face is in sealing contact with the outer housing inner circumference. A plurality of seal elements of a soft ductile metal may be included on the seal face. The housing surface may include a transition circumscribing an axis of the adjustable casing sub, the transition defining a change in diameter of the housing, wherein on one side of the transition a clearance exists between the seal and the housing, and the other side of the transition defines the seal surface where the seal is put into interfering and sealing engagement with the seal surface. The transition may be on the outer diameter of the inner housing, or on the inner diameter of the outer housing.

The seal, in one embodiment, has an elongate height aligned with the casing sub axis, the seal face comprising bands of ductile metal inlays coaxially circumscribing the body outer surface, the inlays in sliding contact with the outer housing inner surface, and the seal has an opposite

side containing a sealing surface disposed on the end of a spring like cantilever member, the elastic deformable sealing surface compressively engagable with the outer circumference of the inner housing.

Also disclosed herein is a well production apparatus comprising a first housing and a second housing coaxially and telescopingly engaged with the first housing with an improved seal between the housings. The seal comprises a radial seal body circumscribing an axis, the body having an elongate section aligned with the axis, elastically deformable cantilevered arms extending from the respective ends of the elongate section, sealing members extending from the end of the cantilevered arms configured for sealing engagement with one of the housings on a first side of the seal body, and a plurality of ductile metal inlays on a side of the seal body opposite to the first side. A transition is formed on one of the housings defining a transition to a sealing surface on the housing. The seal body is radially stretched when in contact with the sealing surface to put the seal members in sealing contact with the sealing surface.

The present disclosure also include an adjustable casing sub, the sub including an upper end mechanically couplable to a platform, a lower end mechanically couplable to a casing string, a first housing, a second housing, wherein the housings are telescopingly insertable within one another, an energizing sleeve provided within one of the housings, elongated splines formed on the energizing sleeve inner diameter for rotating the energizing sleeve, a change in diameter radially circumscribing one of the housings defining a transition from a clearance portion to a sealing surface on the housing, a radial annulus between the first and second housing extending across the transition, and a radial seal disposed in the annulus and axially moveable therein, and the seal energized into sealing engagement with the sealing surface when urged past the transition from the clearance portion.

BRIEF DESCRIPTION OF DRAWINGS

Some of the features and benefits of the present invention having been stated, others will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a side view of an offshore rig with a casing string extending to the seafloor, the casing string having an adjustable casing sub.

Fig. 2 is a side cutaway view of an embodiment of an adjustable casing sub.

Fig. 3 is a side cross sectional view of a seal for an adjustable casing sub prior to being energized.

Fig. 4 is a side cross sectional view of the seal of FIG. 3 after being energized.

Fig. 5 is a side cross sectional view of an embodiment of a seal for use in an adjustable casing sub.

Fig. 6 is a side cross sectional view of an embodiment of a seal for an adjustable casing sub prior to being energized.

Fig. 7 is a side cross sectional view of the seal of FIG. 6 after being energized.

While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to that embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

The device described herein provides a metal seal for use in an adjustable casing sub. The metal seal includes a compressible surface having a ductile metal insert that is also lubricating when axially sliding along an opposing sealing surface. The seal may also include an elastically deformable member on the opposing side of the compressible surface that elastically deforms under a compressive load, and due to its elasticity imparts a sealing force on its respective sealing surface.

With reference now to FIG. 1, an example of an offshore rig 20 is provided in a side view. The offshore rig 20 comprises a platform 22 situated above the level of the sea 21 with a derrick structure 24 attached to the top of the platform 22. Support legs 26 extend from the bottom of the platform and attach on the sea floor 28. A subsea wellhead 30 is formed over a wellbore 31. A tieback casing string 34 extends upward from the subsea wellhead and is coupled with a surface wellhead 32 that is within the platform 22 of the offshore rig 20. In line with the casing string 34 is an adjustable casing sub 36. As is known, insertion of the adjustable casing sub 36 can adjust the length of the casing string 34 to a predetermined length and can also tension the casing string 34.

A partial cross-sectional view of an example of an adjustable casing sub 40 is shown in FIG. 2. The adjustable casing sub comprises a generally annular inner housing body 42 that partially coaxially extends into an outer sleeve 50. The outer sleeve 50 is an annular member with its inner diameter roughly equal to the outer diameter of the inner housing body 42. These respective dimensions allow insertion and telescoping coaxial movement of the inner housing body 42 within the outer sleeve 50. A ratchet ring housing 46 is attached to the lower terminal end of the outer sleeve 50. The ratchet ring housing 46, which is also annular, coaxially circumscribes a portion of the inner housing body 42 below the terminal end of the outer sleeve 50. Teeth 48 are provided on the inner circumference of the ratchet ring housing 46 on its lower skirt section. A ratchet ring 44 is formed on the outer circumference of the inner housing body 42 and profiled on its outer surface with teeth corresponding to the teeth 48 on the ratchet ring housing 46. The combination of ratchet ring housing 46 and ratchet ring 44 comprise a ratchet assembly 47 that permits movement of the ratchet ring housing 46 downward or away from the outer sleeve 50 while preventing upward movement of the ratchet ring housing 46.

An annular traveling sleeve 54 is coaxially affixed within a portion of the outer sleeve 50. The traveling sleeve 54 is profiled on its inner circumference and at its lower end, in the embodiment illustrated the profiles comprise elongated torque splines 52. The splines 52 extend generally parallel to the axis A_X of the adjustable casing sub 40. Also coaxially disposed within the outer sleeve 50 is an annular fixed sleeve 51 having an outer diameter less than the inner diameter of the traveling sleeve 54. The dimensions of the fixed sleeve 51 and the outer sleeve 50 form an annulus 49 therebetween. Threads 55 are formed on the outer circumference of the upper end of the traveling sleeve 54, and corresponding threads 53 are formed on the outer diameter of the fixed sleeve 51.

The respective inner and outer diameters of the inner housing body 42 in the outer sleeve 50 form a housing annulus 45 between these two members. The annulus 45 is an annular void with a seal assembly 59 disposed therein. The seal assembly 59 includes a metal sealing face in contact with one of either the inner or outer housings to seal the coupling connection between the inner housing body 42 and outer sleeve 50. The embodiment of FIG. 2 also illustrates an energizing sleeve 56 for urging the seal assembly 59 into an energized sealing configuration.

FIG. 3 provides a side cross-sectional view of an embodiment of a seal assembly. In this figure, the lower end of the traveling sleeve 54 connects to the energizing sleeve 56 via a locking element 58. In this embodiment, the locking element 58 comprises a split ring compressed into respective channels formed in the traveling sleeve 54 and the energizing sleeve 56. The energizing sleeve 56 is illustrated as a ring-like member extending around the lower circumference of the traveling sleeve 54. A sealing element 57 may optionally be provided in a space between the outer surface of the energizing sleeve 56 and the inner radius of the outer sleeve 50. In this embodiment, the energizing sleeve 56 outer diameter is substantially the same as the outer sleeve 50 inner diameter. The energizing sleeve 56 and outer sleeve 50 are in sliding contact.

The energizing sleeve 56 lower portion terminates in an inwardly directed lip 63 that extends away from the outer sleeve 50. An inner housing nut 61 is shown coaxially adjacent within the lower portion of the energizing sleeve 56. The inner housing nut 61 is a largely annular member having a shoulder formed on its upper end that extends outward toward the outer sleeve 50 to form a cooperating surface with the lip 63 on the lower end of the energizing sleeve 56. The lower terminal end of the inner housing nut is threadingly coupled to the upper terminal end of the inner housing body 42. A shear pin 60 radially extends inward from the energizing sleeve 56

outer diameter to the inner housing nut outer diameter. The shear pin 60 is disposed below the point where the lip 63 and the shoulder 65 are coupled.

An annular seal pocket 64 is shown radially disposed between the outer diameter of the inner housing body 42 and the inner circumference of the outer sleeve 50. The annular seal pocket 64 axially extends on one end from the outer sleeve 50 to a radial ledge 43 in the inner housing body 42 radially extending outward to the inner radius of the outer sleeve 50. An optional ring seal 69 is shown disposed in the annular seal pocket 64 adjacent the radial ledge 43. A seal 62 is shown positioned within the annular seal pocket 64; a side cross-sectional view of an embodiment of the seal 62 is illustrated in FIG. 5. The seal 62 of FIG. 5 comprises a seal body 66, cantilever members 68 shown on an inner diameter, and metal inlays 74 depicted on an outer surface of the seal 62. The body 66 has an elongate height with respect to its thickness, and in the embodiment of FIG. 3 the elongate portion is largely parallel to the axis of the adjustable casing sub 40. The cantilever members 68 comprise elongate cantilever legs 70 having sealing members 72 on their free end. The sealing members 72 face away from the body 66.

The body 66 and cantilever members 68 may be comprised of materials such as stainless steel, titanium, or any elastically deformable material capable of withstanding an applied distributed force without permanently deforming. In one example of use, the force is about 40,000 lbf/in², and another embodiment the force is about 30,000 lbf/in², and yet another embodiment the force is about 25,000 lbf/in². The metal inlays 74 are comprised of a soft ductile metal plastically deformable upon applied sealing loads. Moreover, the inlays 74 should compress when the seal 62 placed in sealing engagement. In one optional embodiment, the metal inlays 74 also provide lubricity such that when sliding across an opposing sealing surface the resultant coefficient of friction is less than that if the metal inlay 74 were made from a less ductile or harder material.

Examples of soft metal candidates include lead, copper, silver, gold, zinc, and alloys thereof. The inlays 74 can comprise all soft metal, or be a harder material having a film, coating, or plating comprising a soft metal.

Referring again to FIG. 3, a transition 67 on the inner housing body 42 identifies a change in diameter of the inner housing body 42. Preferably, the inner housing body 42 outer diameter between the transition 67 and the energizing sleeve 56 does not exceed the seal 62 inner diameter. This allows clearance for the seal 62 when in the portion of the annular seal pocket 64 between the transition 67 and the energizing sleeve 56. The annular seal pocket 64 cross-section or thickness reduces between the transition 67 and the radial ledge 43. As seen in FIG. 4, the dimensional change in the annular seal pocket 64 at the transition 67 results in an interference fit when moving the seal 62 between the transition 67 and the radial ledge 43. The interference fit energizes the seal 62 when it is urged into the portion of the annular seal pocket 64 between the transition 67 and the radial ledge 43. When the seal 62 is in the interference position the body 66 is radially stretched. The increased inner housing body 42 diameter past the transition 67 contacts the sealing members 72 to elastically deform the cantilever legs 70. The elastic deformation produces an opposing sealing force between the sealing members 72 and the inner housing body 42 outer circumference to form a seal between these two surfaces. Additionally, the increased inner housing body 42 diameter also radially urges the inlays 74 against the outer sleeve 50 inner circumference. This plastically deforms the inlays 74 to form a sealing surface between the metal inlays 74 and the outer sleeve 50.

Radially stretching the seal 62 around the increased diameter of the inner housing body 42 effectively increases the seal diameter to actively engage the mating seal surface on the seal 62 inner and outer diameters. Optionally, the side of the seal 62 having the metal inlay 74 and the

side having the cantilever 68 may be reversed such that the metal inlays 74 are in contact with the outer circumference of the inner housing body 42 and the cantilevers 68 and their respective sealing members 72 are in contact with the outer sleeve 50 inner circumference.

With respect to the adjustable casing sub 40, the seal 62 may be energized prior to or after tensioning. In one example of use, the casing sub 40 is secured on its lower end to the casing string 34 and an upper portion of the casing sub 40 is attached to a section having a hanger to be landed within the surface wellhead 32. After engaging the ratchet ring housing 46 over the ratchet ring 44, the casing string is further tensioned by an inserted running or torque tool (not shown) within the casing string and in engagement with the torque splines 52. The tool rotates the torque splines 52 and traveling sleeve 54 counter-clockwise engaging the threads 55 on the traveling sleeve 54 with the threads 53 on the outer sleeve 50. Energizing ring 56 does not rotate with the traveling sleeve 54. Since the traveling sleeve 54 is coupled with the inner housing body 42, as previously described, upwardly moving the traveling sleeve 54 pulls the inner housing body 42 upward to tension the casing string. When a desired amount of tension in the string has been reached the running tool rotation may be reversed, thereby downwardly motivating the traveling sleeve 54 within the outer housing 50 to set or energize the seal 62.

The locking interaction between the ratchet ring 44 and the ratchet ring housing 46 prevents inner housing body 42 movement relative to the outer sleeve 50 when downwardly motivating the traveling sleeve 54. Instead, continued downward force will fracture the shear pin 60, thereby allowing energizing sleeve 56 downward movement with respect to the inner housing nut 61 without rotation. As previously noted, traveling sleeve 54 upward movement does not apply a shear force to the shear pin 60 due to the inner locking connection between the lip 63 and shoulder 65. Continued downward movement of the energizing sleeve 56 urges the seal 62

within the annulus 64 below the transition 67, as shown in side view in FIG. 4. Whether or not the step of energizing the seal 62 occurs prior to tensioning the casing string or after tensioning, at some point a sliding action will occur between the seal 62 and a sealing surface of either the outer sleeve 50 or the inner housing body 42. Accordingly, the ductile and lubricating effect of the metal inlay is operative in either scenario of operation.

The cantilever member is not limited to the embodiment illustrated in the figures, but can include any elastically deformable configuration. In addition to being radially stretched, the seal can be radially compressed to affect the energizing configuration. One of the advantages of the device described herein is the use of metal sealing without the need for any elastomer.

FIGS. 6 and 7 provide a side view of an alternative example of a seal for use in an adjustable casing sub. In this embodiment the seal is integral with either an inner or an outer housing. With reference now to FIG. 6, a portion of the inner housing body includes a seal assembly 76 where the seal assembly includes a mid-section 78 and inlays 80 disposed on one side of the mid-section 78. The outer housing includes an outer housing seal surface 82 with a radial transition 84 formed along a portion of the sealing surface 82. Additionally, the mid-section 78 of the seal assembly 76 is thicker than the housing. In FIG. 7, the inner housing body 42 has been coaxially telescopingly inserted within the outer sleeve 50, and the mid-section 78 has slid past the transition 84 and into a reduced diameter portion. Moving the seal assembly 76 below the transition 84 produces a compressive and sealing contact between the seal assembly 76 and the outer housing seal surface 82. Accordingly, in this configuration, an energized sealing surface between an inner housing and an outer housing can be formed integral with the step of tensioning within an adjustable casing sub.

It should be pointed out that in the configuration illustrated in FIGs. 6 and 7, the seal is not limited to being placed on the inner housing, but can be situated on the outer sleeve 50. When made part of the inner housing body 42 the sealing surface is radially compressed when put into the energizing situation. Conversely, when the seal is disposed on the outer sleeve it is radially expanded during sealing. The sliding seal being radially compressed or expanded generates stored energy that imparts an increased contact stress that is sufficient to create a metal-to-metal seal. Accordingly, embodiments exist wherein the metal seal has a bearing stress of between 5,000 pounds per square inch and 30,000 pounds per square inch. Based on particular applications, however, this sealing stress can be increased.

It is to be understood that the invention is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation. Accordingly, the invention is therefore to be limited only by the scope of the appended claims.

CLAIMS

1. A tubular assembly between a platform and a subsea wellhead, the tubular assembly comprising:
 - an adjustable casing sub coupled between the subsea wellhead and the platform, the adjustable casing sub comprising, an outer housing, an inner housing selectively insertable within the outer housing and having a transition that defines a change in length of an outer radius of the inner housing, an annulus formed between the inner and outer housings, at least one of the housings have a seal surface in the annulus;
 - a seal that moves from an initial position to a sealing position in the annulus adjacent the seal surface, the seal having an outer circumference with a metal face and an inner surface with cantilevered members; and
 - a seal energizing system contained within the adjustable casing sub, so that when the seal is urged to the sealing position to where the outer radius of the inner housing is increased by the seal energizing system, the metal face is urged radially outward into sealing contact with an inner surface of the outer housing by contact of the cantilevered members with the outer radius of the inner housing.
2. The tubular assembly of claim 1 wherein when the seal is moved to the portion of the inner housing having the larger radius, ends of the cantilevered members distal from the seal are elastically deformed radially outward to in turn create a sealing force by urging the metal face against the inner surface of the outer housing.
3. The tubular assembly of claim 1, wherein the metal face comprises a material selected from the list consisting of silver coated metal, a eutectic alloy, an indium alloy, and combinations thereof.
4. The tubular assembly of claim 1, wherein the metal face includes axially spaced apart ductile metal inlays that each engage the inner surface of the outer housing when the seal is in the sealing position.
5. An adjustable casing sub mechanically attachable between a platform and a subsea wellhead assembly, the casing sub comprising:
 - a first housing;
 - a second housing, wherein the housings are telescopingly insetable within one another;
 - an energizing sleeve provided within one of the housings;
 - profiles formed on the energizing sleeve inner diameter for rotating the energized sleeve;
 - a change in diameter circumscribing one of the housings, defining a transition from a clearance portion to a sealing surface on the housing;
 - a radial annulus between the first and second housing extending across the transition; and

a radial seal disposed in the annulus and axially moveable therein, the seal comprising an annular body, a cantilevered leg with an end attached to an inner circumference of the body, a metal face on an outer circumference of the body, the seal energized into sealing engagement with the sealing surface when urged past the transition from the clearance portion.

6. The adjustable casing sub of claim 5, wherein the first housing is insertable within the second housing and the transition is provided on the first housing outer diameter.

7. The adjustable casing sub of claim 6 further comprising deformable metal inlays being on the seal body on a side opposite to the seal members, the deformable metal inlays in compressible sealing engagement with the second housing inner diameter.

8. The adjustable casing sub of claim 6, wherein the first housing is insertable within the second housing and the transition is provided on the second housing inner diameter.

9. The adjustable casing sub of claim 8, further comprising deformable metal inlays on the seal body on a side opposite to the seal members, the deformable metal inlays in compressible sealing engagement with the first housing outer diameter.

10. The adjustable casing sub of claim 5, wherein the seal is integrally formed on the first housing outer diameter, the first housing is insertable within the second housing, and the transition and sealing surface are on the second housing inner diameter, the seal further comprising plastically deformable metal inlays on an outer surface of the seal.

11. The adjustable casing sub of claim 10, wherein the plastically deformable metal inlays are in compressible sealing engagement with the sealing surface.

12. The adjustable casing sub of claim 5, wherein the seal is integrally formed on the first housing inner diameter, the second housing is insertable within the first housing, and the transition is on the second housing inner diameter, the seal further comprising plastically deformable metal inlays on an outer surface of the seal.

13. The adjustable casing sub of claim 12, wherein the plastically deformable metal inlays are in compressible sealing engagement with the sealing surface.