

SEAL WITH SOFT MATERIAL INLAY

CROSS REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of co-pending U.S. Provisional Application Serial No. 61,879,810, filed September 19, 2013, titled “Seal With Soft Material Inlay,” the full disclosure of which is hereby incorporated herein by reference in its entirety for all purposes.

BACKGROUND OF THE DISCLOSURE

1. Field of the Disclosure

[0002] The disclosure relates to wellhead assemblies. In particular, the disclosure relates to an apparatus and method for sealing between inner and outer wellhead members.

2. Brief Description of Related Art

[0003] Seals are used between inner and outer wellhead tubular members to contain internal well pressure. The inner wellhead member may be a casing hanger, and the outer wellhead member may be a wellhead housing. Typically, the casing hanger sits inside the housing bore, and an annular seal is positioned between the casing hanger and the housing. Alternatively, the inner wellhead member may be a tubing hanger that supports a string of tubing extending down into the well, and the outer wellhead member may be a wellhead housing, production tree, or a tubing head. The exterior of the inner wellhead member is spaced from the inner bore of the outer wellhead member, resulting in a pocket for receiving an annular seal. The annular seal serves to seal the space between the inner and outer wellhead members.

[0004] There are many types of annular seals, including rubber, rubber combined with metal, and metal-to-metal. One metal-to-metal seal in use has a U-shape in cross section, having inner and outer walls or legs separated from each other by an annular clearance, called a annular pocket. An energizing ring, which has smooth inner and outer diameters, is pressed into the annular pocket to force the legs apart to seal in engagement with the exterior of the inner wellhead member and the inner bore of the outer wellhead member.

[0005] A set of wickers can be located on sealing surfaces of both the exterior of the inner wellhead member and the inner bore of the outer wellhead member. The wickers sealingly engage outer and inner legs of the annular seal and lock the annular seal into place. In some known systems, in order to achieve adequate sealing between the wickers and the legs upon energization, the annular seal has to be made of a metal that is significantly softer than the metal of the wickers. Otherwise, the wickers deform when they came into contact with legs. An annular seal made of a soft metal, however, has a low retrieval load capability and a low fatigue capability, meaning that the seal can have a shorter operating life and be difficult to retrieve. The use of a soft metal to form the entire seal assembly can cause the seal to deform and break during retrieval of the seal assembly, causing increased time and costs associated with the retrieval process. In addition, the use of a soft metal for the entire seal can result in a low fatigue life of the seal assembly.

SUMMARY OF THE DISCLOSURE

[0006] Systems and methods of the current application provide a composite seal member body made with high strength metal material with a soft inlay along at least one of the sealing surfaces. This configuration allows for higher wicker penetration and lockdown capability to be provided by the soft inlay. An improved fatigue life and higher retrieval force capability is provided by the high strength seal member body.

[0007] In an embodiment of the present disclosure, a wellhead with an axis includes an inner wellhead member that is tubular and has an exterior wall that includes a plurality of inner member wickers extending outwardly therefrom. An outer wellhead member is tubular and has an interior wall that includes a plurality of outer member wickers extending inwardly therefrom. A seal assembly is inserted between the inner and outer wellhead members. The seal assembly includes a seal member body having an inner leg and an outer leg circumscribing the inner leg and coupled to the inner leg by a base portion. The inner leg has an inner diameter positioned adjacent the inner wellhead member and the outer leg has an outer diameter positioned adjacent the outer wellhead member. An energizing ring is selectively located between the inner leg and the outer leg to force the legs radially apart from each other. An inlay is located along a portion of at least one of the inner diameter and outer diameter, positioned to sealingly engage the wickers, the inlay being located in a single groove configured so that no part of the seal member body contacts the exterior wall of the inner wellhead member or the interior wall of the outer wellhead member. The inlay has a smooth outer surface flush with the diameter and is made of a material softer than the inner wellhead member, the outer wellhead member, and the seal member body.

[0008] In an alternate embodiment of the present disclosure, a wellhead assembly with an axis includes an outer wellhead member, the outer wellhead member being tubular and having an interior wall that includes a plurality of outer member wickers extending radially inwardly therefrom. An inner wellhead member is tubular and has an exterior wall that includes a plurality of inner member wickers extending radially outwardly therefrom. The inner wellhead member is operable to land within the outer wellhead member, defining an annular pocket between the inner wellhead member and the outer wellhead member. A seal assembly is located in the annular pocket, the seal assembly having a seal member body having an inner leg and an outer leg, the outer leg circumscribing the inner leg and coupled to the inner leg by a base portion. An outer diameter of the inner leg positioned adjacent the inner wellhead member and an inner diameter of the outer leg positioned adjacent the outer wellhead member. An inner inlay is located along a portion of the outer diameter of the inner leg and an outer inlay located along an inner diameter of the outer leg. Each of the inlays has a smooth outer surface flush with the diameter and made of a material softer than the inner and outer wellhead members and softer than the seal member body. An annular energizing ring selectively urges the inner inlay into sealing engagement with the inner member wickers and the outer inlay into sealing engagement with the outer member wickers. At least one of the inlays has an axial length greater than an axial length of the wickers engaged by such inlay.

[0009] In yet another embodiment of the present disclosure, a method is disclosed for sealing an inner wellhead member to an outer wellhead member. The inner wellhead member is tubular and has an exterior wall that includes a plurality of inner member wickers extending outwardly therefrom. The outer wellhead member is tubular and has an interior wall that includes a plurality of outer member wickers extending inwardly therefrom. A seal assembly is landed

between the inner and outer wellhead members, the seal assembly having a seal member body with an inner leg with an outer diameter, and an outer leg with an inner diameter. The outer leg circumscribes the inner leg and is coupled to the inner leg by a base portion. An inner inlay is located in a single groove is positioned along the outer diameter of the inner leg adjacent the inner wellhead member, and an outer inlay located in a single groove is positioned along the inner diameter of the outer leg adjacent the outer wellhead member. Each of the inlays has a smooth outer surface flush with the diameter and is made of a material softer than the inner and outer wellhead members and softer than the seal member body. The inner inlay is urged into sealing engagement with the inner member wickers and the outer inlay is urged into sealing engagement with the outer member wickers with an annular energizing ring so that no part of the seal member body contacts the exterior wall of the inner wellhead member or the interior wall of the outer wellhead member.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The present technology will be better understood on reading the following detailed description of nonlimiting embodiments thereof, and on examining the accompanying drawings, in which:

[0011] Figure 1 is a side cross-sectional view of a seal assembly with an energizing ring unset in accordance with an embodiment of the disclosure;

[0012] Figure 2 is a side cross-sectional view of the assembly of Figure 1, with the energizing ring in the set position;

[0013] Figure 3 is an enlarged side cross-sectional view of wickers and a seal member outer leg without a soft material inlay;

[0014] Figure 4 is an enlarged side cross-sectional view of wickers and a seal member outer leg that includes a soft material inlay; and

[0015] Figure 5 is an enlarged side cross-sectional view of wickers engaging a seal member outer leg that includes a soft material inlay in accordance with an embodiment of the disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0016] The foregoing aspects, features, and advantages of the present technology will be further appreciated when considered with reference to the following description of preferred embodiments and accompanying drawings, wherein like reference numerals represent like elements. In describing the preferred embodiments of the technology illustrated in the appended drawings, specific terminology will be used for the sake of clarity. However, the technology is not intended to be limited to the specific terms used, and it is to be understood that each specific term includes equivalents that operate in a similar manner to accomplish a similar purpose.

[0017] Referring to Figure 1, an embodiment of the disclosure shows a portion of a wellhead assembly 1, which has an axis Ax and includes outer wellhead member 2. Outer wellhead member 2 of this example is shown as a high-pressure wellhead located at the upper end of a well (not shown), such as a subsea hydrocarbon well or a surface hydrocarbon well. Outer wellhead member 2 is annular and has an axial bore 4 located therein.

[0018] In the embodiment shown, an inner wellhead member 6 is landed within bore 4. Inner wellhead member 6 may be a casing hanger or other tubular member. In alternate embodiments, inner wellhead member 6 may be a tubing hanger that supports a string of tubing extending down into the well, and outer wellhead member 2 may be a production tree, a tubing head, or other tubular wellhead member.

[0019] Inner wellhead member 6 is positioned within the bore 4 such that an exterior wall 8 of inner wellhead member 6 is substantially parallel to an interior wall 10 of outer wellhead member 2. Clearance between the exterior wall 8 of the inner wellhead member 6 and the interior wall 10 of the outer wellhead member 2 defines annular pocket 9. A plurality of inner member wickers 12a can be provided on the exterior wall 8 of inner wellhead member 6,

extending radially outward from exterior wall 8. Similarly, a plurality of outer member wickers 12b can be located on the interior wall 10 of the outer wellhead member 2 radially across from inner member wickers 12a and extend radially inward from interior wall 10. In one embodiment, wickers 12a, 12b are not threads, but can be grooves defined by parallel circumferential ridges 13a, 13b and valleys 15a, 15b. Ridges 13a, 13b and valleys 15a, 15b may have generally triangular cross-sections.

[0020] Seal assembly 14 is configured to sit in annular pocket 9 between exterior wall 8 of inner wellhead member 6 and interior wall 10 of outer wellhead member 2. Seal assembly 14 may include a seal member body 16. Seal member body 16 is annular and has a generally U-shaped cross-section, defining an outer wall or leg 18 and a substantially parallel inner wall or leg 20. Legs 18, 20 are connected together at the bottom by a base portion 21. Optionally, the inner diameter 22 of the outer leg 18 and the outer diameter 24 of the inner leg 20 can be smooth cylindrical surfaces. An annular space or gap 26 separates the legs 18, 20. In the example embodiments shown, inner leg 20 has a shorter axial length than outer leg 18; inner leg 20 extending a shorter axial distance from base portion 21 than outer leg 18.

[0021] Inner diameter 25a of inner leg 20 can include inner inlay 28a and outer diameter 25b of the outer leg 18 can include outer inlay 28b. In some embodiments, such as that shown in Figure 1, inlays 28a, 28b may be present on both legs 18, 20. In other embodiments, an inlay 28a, 28b may be present on only one leg. Each inlay 28a, 28b is located within a single groove with a cylindrical inner diameter base on inner diameter 25a of inner leg 20 or outer diameter 25b of outer leg 18, as applicable. There are no intermediate ridges on the inner diameter 25a of inner leg 20 or outer diameter 25b of outer leg 18 along the axial extent of inlays 28a, 28b between a top edge and bottom edge of inlays 28a, 28b.

[0022] In the example embodiments of Figures 1-2, inner inlay 28a extends generally to the tip at the upper end of inner leg 20, opposite base portion 21 so that the upper end of inner inlay 28a reaches the upper end of inner leg 20. When seal assembly 14 is located within annular pocket 9, the entire axial length of inner inlay 28a engages inner member wickers 12a. In the example embodiments of Figures 1-2, outer inlay 28b has an axial length somewhat greater than an axial extent of outer member wickers 12b so that the upper edge of inlay 28b is above the upper edge of wickers 12b and the lower edge of outer inlay 28b is below the lower edge of wickers 12b and outer inlay 28b engages each of the ridges 13b and valleys 15b of outer member wickers 12b. When energized, no portion of the seal member body 16 contacts either the outer wellhead member 2 or the inner wellhead member 6 in the region of wickers 12a, 12b. Only inlays 28a, 28b contact wickers 12a, 12b. In certain embodiments, no portion of the seal member body 16 contacts either interior wall 10 of outer wellhead member 2 or exterior wall 8 of inner wellhead member 6. A lower leg portion of seal member body 16 may land on an upward facing shoulder of inner wellhead member 6, as seen in the example of Figure 1.

[0023] Inlays 28a, 28b have a radial depth greater than a wicker bite depth of wickers 12a, 12b so that wickers 12a, 12b extend into inlays 28a, 28b, but not entirely through the radial depth of inlays 28a, 28b. The wicker bite depth is the distance that wickers 12a, 12b penetrate into inlays 28a, 28b. Inlays 28a, 28b have smooth outer surfaces 29, 27 free of grooves. Outer surface 29 of inlay 28a is flush with inner diameter 25a of inner leg 20 and outer surface 27 of inlay 28b is flush with outer diameter 25b of the outer leg 18.

[0024] Inlays 28a, 28b are made of a material that is softer than the wickers 12a, 12b. In accordance with an embodiment of the disclosure, soft material inlays 28a, 28b may be made of a soft metal such as brass, certain aluminum alloys and certain steel alloys, or can be made of a

non-metal material, such as epoxy. In some embodiments the material of the seal member body 16 may be about two times harder than the material of the soft material inlays 28a, 28b. In other embodiments, the material of the seal member body 16 may be up to four or more times harder than the material of the soft material inlays 28a, 28b. Tensile strength is directly proportional to hardness and in some embodiments, the soft material inlays may be made of, for example, a material with a tensile yield strength of 30 ksi to 70 ksi. In certain embodiments, the seal member body 16 may be made up of a high tensile yield strength metal, such as material with a tensile yield strength of 60 ksi to 140 ksi.

[0025] In certain embodiments, the material of wickers 12a, 12b may be about two times harder than the material of the soft material inlays 28a, 28b. In alternate embodiments, the material of wickers 12a, 12b may be up to four or more times harder than the material of the soft material inlays 28a, 28b. The material of wickers 12a, 12b can be made of a of a high tensile yield strength metal, such as, for example, a material with a tensile yield strength of 60 ksi to 140 ksi.

[0026] Attachment of inlays 28a, 28b to seal member body 16 may occur during the manufacturing process. For example, the soft metal that makes up the soft material inlays 28a, 28b may be welded to the raw material from which the seal member body 16 will be made. After welding, the raw material and soft metal may be machined together to form the seal member body 16, with the soft metal positioned to form inlays 28a, 28b on the surface of the seal member body 16.

[0027] An energizing ring 30 can be employed to force the legs 18, 20 radially apart from each other and into a permanent deformation in sealing engagement with the wickers 12a, 12b. Specifically, the energizing ring 30 is annular and shaped so that its outer diameter 31 frictionally engages the inner diameter 22 of the outer leg 18 of the seal member body 16,

forcing the outer leg 18 radially outward toward outer member wickers 12b so that outer inlay 28b sealingly engages outer member wickers 12b. Likewise, the inner diameter 33 of the energizing ring 30 frictionally engages the outer diameter 24 of the inner leg 20 of the seal member body 16, forcing the inner leg 20 radially inward toward inner member wickers 12a so that inner inlay 28a sealingly engages inner member wickers 12a. Figure 2 shows an embodiment of the disclosure in which the lowered energizing ring 30 forces the legs 18, 20 into sealing engagement with the wickers 12a, 12b as discussed.

[0028] In an example of operation, in order to seal inner wellhead member 6 to outer wellhead member 2, seal assembly 14 is landed in annular pocket 9 so that inner inlay 28a of inner leg 20 is positioned adjacent inner wellhead member 6 and outer inlay 28b of outer leg 18 is positioned adjacent outer wellhead member 2. Energizing ring 30 can then be pushed into gap 26 to urge inner inlay 28a into sealing engagement with inner member wickers 12a and urging outer inlay 28b into sealing engagement with outer member wickers 12b.

[0029] Figures 4 and 5 show outer member wickers 12b approaching (Figure 4) and then engaging (Figure 5) outer inlay 28b of outer leg 18. Inner inlay 28a can be urged into sealing engagement with inner member wickers 12a and outer inlay 28b can be urged into sealing engagement with outer member wickers 12b until the inlays 28a, 28b completely fill the valleys 15a, 15b along an axial length of each of the inlays 28a, 28b. In accordance with an embodiment of the disclosure, the soft material inlay 28b is made of a material that flows when exposed to high pressure, such as the pressure generated by energizing ring 30 being pushed into gap 26, or the pressure generated by the operating forces applied to wellhead assembly 1, such as hydraulic pressure or thermal expansion forces. Thus, under high pressure conditions, the soft material can flow into the parallel circumferential valleys 15b that are in between the parallel circumferential

ridges 13b. Because inlays 28a, 28b have a greater axial depth than the wickers 12a, 12b, when each seal member body 16 is fully energized, wickers 12a, 12b will not contact the material that makes up the seal member bodies 16.

[0030] In such a way, embodiments of this disclosure provide improved retrieval capability of seal assembly 14 and increased fatigue resistance of the seal member body 16. The use of soft inlays 28a, 28b allows for the use of a high tensile yield strength metal in seal member body 16, while simultaneously allowing for adequate sealing engagement between the wickers 12a, 12b and the legs 18, 20. The result is a seal assembly characterized by a higher lockdown capability, higher retrieval forces, and higher fatigue capability compared to current known seal assemblies.

[0031] While the technology has been shown or described in only some of its forms, it should be apparent to those skilled in the art that it is not so limited, but is susceptible to various changes without departing from the scope of the disclosure. Furthermore, it is to be understood that the above disclosed embodiments are merely illustrative of the principles and applications of the present disclosure. Accordingly, numerous modifications may be made to the illustrative embodiments and other arrangements may be devised without departing from the spirit and scope of the present disclosure as defined by the appended claims.

What is claimed is:

1. A wellhead assembly having an axis, comprising:

an inner wellhead member that is tubular and has an exterior wall that includes a plurality of inner member wickers extending outwardly therefrom;

an outer wellhead member that is tubular and has an interior wall that includes a plurality of outer member wickers extending inwardly therefrom;

a seal assembly inserted between the inner and outer wellhead member, the seal assembly comprising:

a seal member body having an inner leg and an outer leg circumscribing the inner leg and coupled to the inner leg by a base portion;

the inner leg having an inner diameter positioned adjacent the inner wellhead member;

the outer leg having an outer diameter positioned adjacent the outer wellhead member;

an energizing ring selectively located between the inner leg and the outer leg to force the legs radially apart from each other; and

an inlay located along a portion of at least one of the inner diameter and outer diameter, positioned to sealingly engage the wickers, the inlay being located in a single groove configured so that no part of the seal member body contacts the exterior wall of the inner wellhead member or the interior wall of the outer wellhead member, and having a smooth outer surface flush with the diameter and made of a material softer than the inner wellhead member, the outer wellhead member, and the seal member body.

2. The wellhead assembly according to claim 1, wherein the inlay is located on both the inner diameter of the inner leg and the outer diameter of the outer leg.
3. The wellhead assembly according to claim 1, wherein the inlay has a radial depth greater than a wicker bite depth of the wickers.
4. The wellhead assembly according to claim 1, wherein the wickers include a plurality of parallel circumferential ridges and valleys the inlay completely fills the valleys along an axial length of the inlay.
5. The wellhead assembly according to claim 1, wherein the inlay is on the outer leg and the inlay has an upper edge above an upper edge of the wickers and a lower edge below a lower edge of the wickers.
6. The wellhead assembly according to claim 1, wherein the inner leg has a shorter axial length than the outer leg and the inlay is located on the inner leg with an upper edge of the inlay at an upper end of the inner leg.
7. The wellhead assembly according to claim 1, wherein the wickers are formed of a material that has a tensile yield strength that is two to four times the yield strength of the material of the inlay.

8. The wellhead assembly according to claim 1, wherein the seal member body is formed of a material that has a tensile yield strength that is two to four times the yield strength of the material of the inlay.

9. A wellhead assembly having an axis, comprising:

an outer wellhead member, the outer wellhead member being tubular and having an interior wall that includes a plurality of outer member wickers extending radially inwardly therefrom;

an inner wellhead member, the inner wellhead member being tubular and having an exterior wall that includes a plurality of inner member wickers extending radially outwardly therefrom, the inner wellhead member being operable to land within the outer wellhead member, defining an annular pocket between the inner wellhead member and the outer wellhead member;

a seal assembly located in the annular pocket, the seal assembly having a seal member body having an inner leg and an outer leg, the outer leg circumscribing the inner leg and coupled to the inner leg by a base portion;

an inner diameter of the inner leg positioned adjacent the inner wellhead member;

an outer diameter of the outer leg positioned adjacent the outer wellhead member;

an inner inlay located along a portion of the inner diameter of the inner leg and an outer inlay located along an outer diameter of the outer leg, each of the inlays having a smooth outer surface flush with the diameter and made of a material softer than the inner and outer wellhead members and softer than the seal member body;

an annular energizing ring selectively urging the inner inlay into sealing engagement with the inner member wickers and the outer inlay into sealing engagement with the outer member wickers; and wherein

at least one of the inlays has an axial length greater than an axial length of the wickers engaged by such inlay.

10. The wellhead assembly according to claim 9, wherein the at least one of the inlays that has an axial length greater than an axial length of the wickers engaged by such inlay is the outer inlay.

11. The wellhead assembly according to claim 9, wherein the inner inlay extends to an upper end of the inner leg.

12. The wellhead assembly according to claim 9, wherein the wickers have a generally triangular shape in cross section.

13. The wellhead assembly according to claim 9, wherein each of the inlays is located in a single groove having a cylindrical base.

14. The wellhead assembly according to claim 9, wherein the wickers include a plurality of parallel circumferential ridges and valleys, and the inlays completely fill the valleys along an axial length of each of the inlays.

15. The wellhead assembly according to claim 9, wherein the wickers and the seal member body are formed of a material that has a tensile yield strength that is two to four times the yield strength of the material of the inlay.

16. A method for sealing an inner wellhead member to an outer wellhead member, the inner wellhead member being tubular and having an exterior wall that includes a plurality of inner member wickers extending outwardly therefrom, and the outer wellhead member being tubular and having an interior wall that includes a plurality of outer member wickers extending inwardly therefrom, the method comprising:

(a) landing a seal assembly between the inner and outer wellhead members, the seal assembly having a seal member body with an inner leg with an inner diameter, and an outer leg with an outer diameter, the outer leg circumscribing the inner leg and coupled to the inner leg by a base portion;

(b) positioning an inner inlay located in a single groove along the inner diameter of the inner leg adjacent the inner wellhead member, and positioning an outer inlay located in a single groove along the outer diameter of the outer leg adjacent the outer wellhead member, each of the inlays having a smooth outer surface flush with the diameter and made of a material softer than the inner and outer wellhead members and softer than the seal member body; and

(c) urging the inner inlay into sealing engagement with the inner member wickers and the outer inlay into sealing engagement with the outer member wickers with an annular energizing ring so that no part of the seal member body contacts the exterior wall of the inner wellhead member or the interior wall of the outer wellhead member.

17. The method according to claim 16, wherein the wickers include a plurality of parallel circumferential ridges and valleys, and wherein step (c) includes urging the inner inlay into sealing engagement with the inner member wickers and the outer inlay into sealing engagement with the outer member wickers until the inlays completely fill the valleys along an axial length of each of the inlays.
18. The method according to claim 16, further comprising exposing the seal assembly to a high pressure to cause a material of the inlays to flow into the wickers.
19. The method according to claim 16, further comprising selecting an inlay formed of a material with a tensile yield strength of 30 ksi to 70 ksi.
20. The method according to claim 16, further comprising selecting an inlay formed of a material that is at least half as hard as the material of the wickers.