HARD STOP ENERGIZING RING

Field of the Invention:

[0001] This invention relates in general to wellhead assemblies and in particular to an energizing ring profile that allows increased seal setting load capacity when a U-seal is locked down.

Background of the Invention:

[0002] Seals are used between inner and outer wellhead tubular members to contain internal well pressure. The inner wellhead member may be a casing hanger located in a wellhead housing and that supports a string of casing extending into the well. A seal or packoff seals between the casing hanger and the wellhead housing. Alternatively, the inner wellhead member could be a tubing hanger that supports a string of tubing extending into the well for the flow of production fluid. The tubing hanger lands in an outer wellhead member, which may be a wellhead housing, a Christmas tree, or a tubing head. A seal or packoff seals between the tubing hanger and the outer wellhead member.

[0003] A variety of seals located between the inner and outer wellhead members have been employed in the prior art. Figure 1 shows a portion of a seal assembly in the prior art within a wellhead housing 101. Housing 101 is typically located at an upper end of a well and serves as an outer wellhead member. An energizing ring 103 is typically forced downward by a running tool or the weight of a string to force it into a slot 105 defined by a U-type metal seal ring 107. Located below the seal ring 107 is a lower extension 109 that rests on a shoulder 111 formed on an inner wellhead member, such as a hanger 113. As it is forced downward, the energizing ring deforms

inner and outer walls of the seal ring 107 apart into respective sealing engagement with inner and outer wellhead members 113, 101. The energizing ring is typically a solid wedge-shaped member. The deformation of the inner and outer walls exceeds the yield strength of the material of the seal ring 107, making the deformation permanent. Prior art seals may also include elastomeric and partially metal and elastomeric rings. Prior art seal rings made entirely of metal for forming metal-to-metal seals are also employed.

[0004] However, energizing rings of the prior art have a setting load capacity below the full capability of the running tool. In the event that the seal is set with the full force of the running tool, the outer leg of the seal ring 107 will buckle, causing the seal to fail.

[0005] Additionally, cyclic pressure tests of the wellhead cause low-cycle fatigue in the wellhead seal. When the seal is pressurized from above the energizing ring, the energizing ring is forced deeper into the seal pocket which can likewise cause the seal to fail.

[0006] A need exists for a technique that addresses the seal setting problems described above. In particular a need exists for a technique to prevent structural damage to the seal ring caused by too much setting force and low-cycle fatigue.

Summary of the Invention:

[0007] In an embodiment of the present technique, a seal assembly is provided that forms a metal-to-metal seal and has features that enhance sealability in the seal assembly. The seal ring has inner and outer walls separated by a slot and has a bottom portion that contacts an upward facing shoulder of a hanger. A metal energizing ring has a tapered nose that may be pushed into the slot during installation to deform the inner and outer walls into sealing engagement with inner and outer wellhead members having wickers formed thereon. A radial gap exists between the outer wall of the seal and the inner wall of the mating housing. Such a gap is required for installation in the field and is sufficiently large to require plastic deformation of the seal body, but not the energizer ring.

[0008] In an illustrated embodiment, the energizing ring has a 90 degree shoulder extending from the inside surface of the energizing ring positioned to abuttingly contact the top of the inner leg of the seal ring when the seal is fully energized. As the nose travels into the slot, the outer and inner legs of the metal seal ring are forced into sealing engagement with the inner and outer wellhead members. Once the seal has been fully set, the shoulder on the energizing ring prevents the nose of the energizing ring from entering the seal ring any further by transferring the setting load into the inner leg of the seal ring and subsequently into the wickers.

[0009] In an example embodiment, the seal assembly also comprises the energizing ring that engages the slot. The retainer nut rests in a machined gap on the outer surface of the energizing ring. The outer leg of the seal ring is threadedly connected with the retainer ring. The engagement ensures that the seal assembly remains intact as one integral structure during landing, setting, and retrieval operations.

[0010] The combination of stored energy provided for by the energizing ring, the hard stop shoulder configuration of the energizing ring, and the compressible elastomeric seal below the seal ring, advantageously provide enhanced setting capacity and resilience to the wellhead seal assembly.

Brief Description of the Drawings:

[0011] Figure 1 is a sectional view of a seal assembly of the prior art with an energizing ring without a hard stop shoulder set in the seal;

[0012] Figure 2 is a sectional view of the seal assembly of Figure 2 landed between outer and inner wellhead members in an unset position in accordance with an embodiment of the invention;

[0013] Figure 3 is a sectional view of the nose of an energizing ring after entering a slot of a seal ring and deforming walls of the seal ring, in accordance with an embodiment of the invention.

Detailed Description of the Invention:

[0014] Referring to Figure 2, an embodiment of the invention shows a portion of a wellhead assembly that includes a high pressure wellhead housing 101. In this example, the housing 101 is located at an upper end of a well and serves as an outer wellhead member of the wellhead assembly. Housing 101 has a bore 115 located therein. In this example, an inner wellhead member is a casing hanger 113, which is shown partially in Figure 2 within bore 115. Alternately, wellhead housing 101 could be a tubing spool or a Christmas tree, and casing hanger 113 could instead be a tubing hanger, plug, safety valve, or other device. Casing hanger 113 has an exterior annular recess radially spaced inward from bore 115 to define a seal pocket 117. Wickers 119 are located on a portion of the wellhead bore 115 and wickers 121 are located on a portion of the cylindrical wall of seal pocket 117. The wickers comprise triangular grooves parallel to each other. In this example, the profiles of each set of wickers 119, 121 are shown as continuous profiles on the bore 115 and seal pocket 117. However, the wickers 119, 121 may be configured in other arrangements. For instance, the wickers may be only on the bore 101 or only on the casing hangar 113.

[0015] Continuing to refer to Figure 2, a metal-to-metal seal assembly 123 is lowered between the housing 101 and casing hanger 113 and located in seal pocket 117. Seal assembly 123 includes a seal ring 125 formed of a metal such as steel. Seal ring 125 has an inner wall 127 that is an inner seal leg 129 for sealing against the cylindrical wall of casing hanger 113. Seal ring 125 has an outer wall surface 131 comprised of outer seal leg 133 that seals against wellhead housing bore 115. One of the seal legs is shorter than the other. In this embodiment, the upper end of inner leg 129 is lower than the upper end of outer leg 133. Each wall surface 127, 131 is cylindrical and

smooth and engages the wickers 119, 121 when deformed against the bore 115 of the housing 101 and seal pocket 117 of the casing hanger 113. The wickers 119, 121 enhance the grip to aid in the prevention of axial movement of the seal assembly once set.

[0016] In the example Figure 2, seal ring 125 is uni-directional, having an upper section only; however, a seal ring that is bi-directional may optimally be used. The upper section has a slot 135 defined between inner and outer legs 129, 133. The inner and outer surfaces forming slot 135 comprise generally cylindrical surfaces, that when viewed in an axial cross-section are generally parallel and each follow a straight line.

[0017] An annular energizing ring 137 engages slot 135 on the upper side. As shown, the energizing ring 137 has an axis A_R that substantially coincides with an axis (not shown) of the wellhead assembly. Energizing ring 137 is forced downward into slot 135 by a running tool (not shown). Alternatively, seal assembly 123 and energizing ring 137 may be part of a string that is lowered into bore 115, the weight of which forces energizing ring 137 into slot 135. Energizing ring 137 can be formed of metal, such as steel. The mating surfaces of energizing ring 137 and outer seal leg 133 may be formed at a locking taper. Energizing ring 137 has a greater radial thickness than the radial breadth of slot 135.

[0018] The annular energizing ring 137 has a downwardly facing 90° hard-stop shoulder 139 formed on its inner wall 141 positioned to abuttingly contact the top edge of the inner leg 129 of the seal ring 125 when the energizing ring is fully engaged in the seal ring in the set position. When fully set, the nose or lower end of the energizing ring 137 will be spaced above the base of slot 135.

[0019] In an embodiment of the invention, a retaining nut 143 is carried in a gap 145 formed in the outer surface of upper energizing ring 137. Retaining nut 143 is threadedly connected to the outer leg 133 of the seal ring 125. The top edge of the retaining nut forms an upward facing shoulder 147. On the upper end of the outer seal leg 133. Retaining nut 143 has a 90 degree downwardly facing shoulder 149 on its outer surface which makes abutting contact with the top edge 151 of the seal ring 137 when the retaining nut is attached to the seal ring. When in position, retaining nut 143 is positioned to prevent energizing ring 137 from moving out of its run-in position during landing, setting, and retrieval operations.

[0020] Energizing ring 137 has a nose 161 or engaging portion that engages slot 135. Energizing ring 137 has an inner surface 141 and an outer surface 153 for engaging the opposite inner sidewalls of slot 135 in seal ring 125. Inner and outer surfaces 141, 153 may be straight surfaces as shown, or optimally curved surfaces.

[0021] In the example embodiment of Figure 2, a lower extension 155 secures by threads to the lower portion of seal ring 125. The lower extension 155 extends down and comprises a landing nose 157 to facilitate landing on an upward facing shoulder 159 formed on the interior of the casing hanger 113. The shoulder 159 provides a reaction point during setting operations.

[0022] Referring to Figure 3, an enlarged sectional view of the nose 161 of the energizing ring 141 is shown in the set position. The nose 161 may have a vent 163 to prevent hydraulic locking and may have a first tapered surface or portion. The inner and outer legs 129, 133 of the seal ring 125 have chamfers at their upper ends and proximate the opening of the slot 135. In embodiments of the invention, vent passages or penetration holes 163 (Figure 5) may be incorporated across wedge member 161

and through upper energizing ring 137 so that a hydraulic lock condition does not prevent axial make-up of the energizer and seal system.

[0023] As force is applied to the energizing ring 137 (Figure 2), the force on the energizing ring 137 and the reacting force from the shoulder 159 (Figure 3) cause the nose 161 to enter into the slot 135 and thereby deform the legs 129, 133 of the seal ring 125 against the wickers 119, 121 of the housing 101 and hanger 113. Once the legs 129, 133 are set and the energizing ring is in the set position, the hard-stop shoulder 139 makes contact with the top edge of the inner seal leg 129, thereby preventing the energizing ring 137 from moving any further into the slot 135 by transferring the load from the running tool to the upwardly facing shoulder 159 of casing hangar 113 through the energizing ring hard-stop shoulder 139 into the seal ring 125, and thus into the lower extension 155 and the wickers 119, 121. The lower end of energizing ring 137 does not contact the base of slot 135 when fully set.

[0024] In an example of operation of the embodiment shown in Figures 2-3, a running tool or string (not shown) is attached to seal assembly 123 and lowered into the seal pocket 117 Seal assembly 123 may be pre-assembled with energizing ring 137, retaining nut 143, seal ring 125, and extension 155 all connected as shown in Figure 2. The outer wall 131 of outer seal leg 133 will be closely spaced to wickers 119 on the wellhead bore 115. The inner wall 127 of inner seal leg 129 will be closely spaced to the wickers 121 on the cylindrical wall of seal pocket 117. By pushing the energizing ring 137 downward (such as by the running tool) with sufficient force to insert the nose 161 in the slot 135, engagement of nose 161 with the slot 135 causes the inner and outer seal legs 129, 131 to move radially apart from each other as shown in Figures 4 and 5. The inner wall 127 of inner seal leg 129 will embed into wickers

121 in sealing engagement while the outer wall 131 of outer seal leg 133 will embed into wickers 119 in sealing engagement.

[0025] In an additional embodiment (not shown), the wellhead housing 101 could be a tubing spool or a Christmas tree. Furthermore, the casing hanger 113 could instead be a lockdown hanger, tubing hanger, plug, safety valve or other device.

[0026] While the invention has been shown in only one 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 invention. For example, the seal could be configured for withstanding pressure in two directions, if desired, having two energizing rings. In addition, each energizing ring could be flexible, rather than solid.

WHAT IS CLAIMED IS:

1. A metal-to-metal seal assembly for sealing in a seal pocket between inner and outer tubular members of a wellhead assembly, comprising:

a seal ring having an axis, and annular inner and outer legs separated from each other by an annular slot having a run-in radial width;

an annular energizing ring having a nose portion with a radial thickness greater than the run-in radial width of the seal ring, and carried in a run-in position with a nose end at an entrance of the annular slot;

an annular stop shoulder on the energizing ring above the nose end;

the seal ring being energized from the run-in position to a set position by applying an axial energizing force to the energizing ring, so that the energizing ring is pressed into the annular slot causing radial plastic deformation of the annular inner and outer legs of the seal ring into sealing contact with the inner and outer tubular members defining the set position; and

the annular stop shoulder contacting an upper end of one of the legs of the seal ring while in the set position.

2. The assembly according to claim 1, further comprising:

a set of wickers formed in at least one of the seal surfaces, a smooth cylindrical surface adjoining the set of wickers; and

opposing seal surfaces in the bore and on an exterior portion of the inner wellhead member.

3. The assembly according to claim 1, wherein the stop shoulder is perpendicular to the axis.

4. The assembly according to claim 1, wherein the length of the energizing ring below the stop shoulder to the nose end is less than the length of the slot in the seal ring.

5. The assembly according to claim 1, wherein continued axial energy forces applied to the energizing ring after reaching the set point is directed through the stop shoulder to the seal ring.

6. The assembly according to claim 1, wherein the stop shoulder engages the upper end of the inner leg of the seal ring.

7. The assembly according to claim 1, wherein a radial thickness of the energizing ring at the stop shoulder is greater than the radial thickness of the nose part.

8. The assembly according to claim 1, wherein the stop shoulder is located between the nose and an upper end of the energizing ring.

9. The assembly according to claim 1, wherein the nose end is spaced above a base of the slot while the stop shoulder is contacting the upper end of said one of the inner and outer seal legs.

10. A wellhead assembly with an axis, comprising:

an outer wellhead member having a bore;

an inner wellhead member in the bore;

an annular space between the inner and outer wellhead members;

a seal member having inner and outer annular legs defining a slot therebetween, the inner leg having an upper end at a lower elevation than an upper end of the outer leg;

an annular energizing ring in the slot and having an annular stop shoulder extending radially inward from the inner surface of the energizing ring positioned in abutment with the upper end of the inner leg of the seal member while the energizing ring is in a set position, preventing further downward movement of the energizing ring in the slot once the energizing ring reaches the set position.

11. The assembly according to claim 10, further comprising:

a set of wickers formed in at least one of the seal surfaces, a smooth cylindrical surface adjoining the set of wickers; and

opposing seal surfaces in the bore and on an exterior portion of the inner wellhead member.

12. The assembly according to claim 10, wherein the stop shoulder is perpendicular to the axis.

13. The assembly according to claim 10, wherein the length of the energizing ring below the stop shoulder to the nose end is less than the length of the slot in the seal ring.

14. The assembly according to claim 10, wherein continued axial energy forces applied to the energizing ring after reaching the set point is directed through the stop shoulder to the seal ring.

15. The assembly according to claim 10, wherein the stop shoulder is located between the nose and an upper end of the energizing ring.

16. The assembly according to claim 10, wherein the nose end is spaced above a base of the slot while the stop shoulder is contacting the upper end of said one of the inner and outer seal legs.

17. A method for sealing an annular space in a wellhead assembly between inner and outer wellhead members, comprising:

providing wickers on at least one of the inner and outer wellhead members;

providing a seal member having inner and outer annular walls defining a slot therebetween, and an annular energizing ring and having an annular stop shoulder;

inserting the seal member between the inner and outer members;

inserting energizing ring into the slot by a downward force on the energizing ring, causing the inner and outer legs to move radially into sealing engagement with the inner and outer wellhead members and into engagement with the wickers;

continuing to apply the downward force after the stop shoulder contacts an upper end of one of the legs, and directing the downward force through said one of the legs to the wickers.

18. The method according to claim 17, wherein the inner leg is contacted by the stop shoulder and wickers are on the inner wellhead member