

METALLIC SEAL FOR USE IN HIGHLY-CORROSIVE OIL AND GAS ENVIRONMENTS

BACKGROUND

The invention relates generally to metallic seal assemblies for use in sealing components of oil and gas wells. In particular, the invention relates to a seal assembly for use in a highly-corrosive well environment, such as a well having high levels of hydrogen sulfide, carbon dioxide, water, and chlorides.

Oil and gas wells may contain many substances that combine together to create a highly-corrosive environment for oil field equipment. A seal that is used in a highly-corrosive environment that is not able to withstand the corrosive effects of the environment will begin to corrode. Eventually, the integrity of the seal will be lost and the seal assembly will fail.

Wells are generally categorized as being either "sweet" or "sour." A well is categorized as a sweet well if it is only mildly corrosive. Conversely, a well is categorized as a sour well if it is very corrosive. The presence of several different compounds can make a well a sour well, such as hydrogen sulfide, carbon dioxide, chlorides, and free sulfur.

In particular, equipment exposed to corrosive well bore fluids must be able to resist stress corrosion cracking (SCC). Stress corrosion cracking (SCC) is the unexpected sudden failure of normally ductile metals or tough thermoplastics subjected to a constant tensile stress in a corrosive environment, especially at elevated temperature (in the case of metals). This type of corrosion often progresses rapidly. The corrosive environment is of crucial importance, and only very small concentrations of certain highly active chemicals are needed to produce catastrophic cracking, often leading to devastating failure.

Sulfide stress cracking (SSC), or sulfide stress corrosion cracking (SSCC), is a form of stress corrosion cracking. Susceptible alloys, especially steels, react with hydrogen sulfide, forming metal sulfides and elementary atomic hydrogen. Atomic hydrogen,

created as a by-product of a cathodic reaction in the presence of H_2S , diffuses into the metal matrix. Small quantities of hydrogen present inside certain metallic materials make the latter brittle and susceptible to sub-critical crack growth under stress. Some materials may exhibit a marked decrease in their load carrying capacity and fail in a brittle fashion when stressed in an atmosphere containing hydrogen. Both of these processes may be called hydrogen embrittlement.

As oil and gas wells are drilled in deeper and deeper waters, the demand on the materials used in the wells increases. In addition to being able to withstand the corrosive elements present in a well, the materials used must be able to withstand the greater temperatures and pressure requirements for wells drilled in ever deeper waters. As a result, the materials used within a corrosive well typically are selected based on their corrosion-resistance and strength, as well as cost-effectiveness.

As a result, there is a need for a seal assembly that has the strength and corrosion-resistance to form and maintain a seal in the highly-corrosive environment of a deepwater oil or gas well. In particular, there is a need for a seal assembly that has the strength and corrosion-resistance to form and maintain a seal in a corrosive deepwater well, especially under high pressure and high temperature conditions.

BRIEF DESCRIPTION

A technique is provided for sealing components located in highly corrosive environments, such as sour wells operating at high temperatures and pressures. A seal assembly is used to form a seal between components. The seal assembly is comprised of a base metal structure with a softer metal layer over the base metal structure. The purpose of the soft metal layer is to deform and, thereby, form a seal against a surface of an opposing component. The material of the base metal structure is chosen to provide structural integrity to the seal. Ideally, both materials should be selected to be compatible with the corrosive fluids.

Preferably, the base metal structure of the seal is comprised of a corrosion-resistant alloy. Examples of some corrosion resistant alloys commonly used in the oil and gas industry are nickel and cobalt alloys, such as UNS N07718, UNS N07716, UNS

N07725, UNS N09925, UNS R30006 and UNS R31233. In addition, preferably, the metal layer also is comprised of a corrosion-resistant alloy or metal, such as titanium, or a refractory metal, such as tungsten, molybdenum, rhenium and more specifically, tantalum.

DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood when the following detailed description is read with reference to the accompanying drawings in which like characters represent like parts throughout the drawings, wherein:

FIG. 1 is a cross-sectional view of a seal disposed between a wellhead and a wellhead connector, in accordance with an exemplary embodiment of the present technique;

FIG. 1A is a detailed cross-sectional view taken generally along line 1A-1A of FIG. 1, in accordance with an exemplary embodiment of the present technique;

FIG. 2 is a cross-sectional view of a seal disposed between a casing hanger and a wellhead, in accordance with an exemplary embodiment of the present technique;

FIG. 3 is a cross-sectional view of the seal of FIG. 2 activated to form a seal between the casing hanger and the wellhead, in accordance with an exemplary embodiment of the present technique;

FIG. 3A is a detailed cross-sectional view taken generally along line 3A-3A of FIG. 3, in accordance with an exemplary embodiment of the present technique;

FIG. 4 is a cross-sectional view of a seal assembly for a swivel device, in accordance with an exemplary embodiment of the present technique; and

FIG. 4A is a detailed cross-sectional view taken generally along line 4A-4A of FIG. 4, in accordance with an exemplary embodiment of the present technique.

DETAILED DESCRIPTION

Referring generally to FIGS. 1 and 1A, the present invention will be described as it might be applied in conjunction with an exemplary technique, in this case a subsea wellhead assembly 20 comprising a high pressure wellhead 22 and a wellhead connector 24. The wellhead connector 24 is used to connect an object, such as a subsurface tree, to the high pressure wellhead 22. The wellhead connector 24 has a lower portion (not shown) that is disposed over the exterior of the wellhead 22. The wellhead connector 24 has a locking member, such as dogs (not shown) that are moved into engagement with grooves (not shown) formed on the exterior of the wellhead 22. The high pressure wellhead has an inner bore 26 that is coaxial with an inner bore 28 of the wellhead connector 24 when the wellhead connector 24 is secured to the wellhead 22.

A gasket or seal ring 30 is disposed between the high pressure wellhead 22 and wellhead connector 24 to seal the inner bore 26 of the wellhead 22 to the inner bore 28 of the wellhead connector 28. Seal ring 30 is generally T-shaped and has an upper leg 32 and a lower leg 34. In this embodiment, the upper leg 32 and lower leg 34 are symmetrical. Alternatively, the upper leg 32 and lower leg 34 may be asymmetrical. In addition, in this embodiment, each leg has a first seal band 36 and a second seal band 38. In addition, the seal ring 30 is formed so that the first and second seal bands 36, 38 have a conical shape in this embodiment. This enables the seal ring 30 to form a seal against a conical sealing surface 40 of the wellhead connector 24 and a conical sealing surface 42 of the high pressure wellhead 22. The seal ring 30 has a rib 44 that is received into a recess 46 of the wellhead connector 24. The recess 46 forms a pocket between the wellhead connector 24 and a shoulder 48 of the wellhead 22. When the wellhead connector 24 is secured to the wellhead 22, the rib 44 of the seal ring 30 is captured in the recess 46 between the wellhead 22 and the wellhead connector 24.

In the illustrated embodiment, the seal ring 30 is manufactured to be resistant to sulfide stress cracking (SSC) and stress corrosion cracking (SCC). In particular, the seal ring 30 is manufactured to satisfy the requirements for "HH-Sour Service" as set

forth in ANSI/API (Approved American National Standard/American Petroleum Institute) Specification 6A, "Specification for Wellhead and Christmas Tree Equipment." According to Table 3 of ANSI/API Specification 6A, a material satisfies the requirements for "HH-Sour Service" if it is a CRA (Corrosion Resistant Alloy) in compliance with NACE (National Association of Corrosion Engineers) standard: "MR 0175." Section 3.1.30 of ANSI/API Specification 6A defines a Corrosion Resistant Alloy (CRA) as a "nonferrous-based alloy in which any one or the sum of the specified amount of the elements titanium, nickel, cobalt, chromium, and molybdenum exceeds 50% (mass fraction)." NACE MR 0175 is entitled: "Petroleum and natural gas industries-Materials for use in H₂S-containing environments in oil and gas production." Section 3.6 of Part 1 of NACE MR 0175 defines a corrosion-resistant alloy (CRA) as an "alloy intended to be resistant to general and localized corrosion of oilfield environments that are corrosive to carbon steels." Here, a corrosion-resistant alloy (CRA) is defined as a material that is "an alloy intended to be resistant to general and localized corrosion of oilfield environments that are corrosive to carbon steels" and/or "a nonferrous-based alloy in which any one or the sum of the specified amount of the elements titanium, nickel, cobalt, chromium, and molybdenum exceeds 50% (mass fraction)."

In the illustrated embodiment, the seal ring 30 is comprised of a metal body 50 that is covered with a metal layer 52. In the illustrated embodiment, the metal body 50 comprises a corrosion-resistant alloy (CRA). Corrosion resistant alloys are well suited for service in extreme environments. These alloys form a thick and stable oxide layer on their surface protecting the alloy from the corrosive environment. However, the metal body 50 may be comprised of a metal other than a CRA.

Examples of corrosion resistant alloys that may be used for the metal body 50 are nickel and cobalt alloys such as UNS N07718, UNS N07725, UNS N09925, UNS R30006 and UNS R31233. UNS N07718, UNS N07716, UNS N07725 and UNS N09925 are generally classified as precipitation-hardenable nickel alloys. UNS R30006 and UNS R31233 are generally categorized as cobalt based alloys. These nickel and cobalt alloys and others (not listed) are intentionally alloyed and heat treated to provide the corrosion resistance and strength. The combination of elements

makes the alloy resistant to hydrogen embrittlement and stress-corrosion cracking. These alloys are resistance to general corrosion, pitting, crevice corrosion, and stress-corrosion cracking in many aqueous environments, including sulfides and chlorides. However, an alloy other than the aforementioned alloys may be used.

Alloys UNS N07718, UNS N07716, UNS N07725, UNS N09925, and UNS R31233 are listed in Annex A of Part 3 of NACE MR 0175 as CRAs. Part 3 of NACE MR 0175 is entitled: "Cracking-resistant CRAs (corrosion-resistant alloys) and other alloys." Annex A is entitled: "Environmental cracking-resistant CRAs and other alloys." Precipitation-hardened nickel-based alloys that are CRAs and their environmental and material limits are listed in Section A.9 of Annex A by their UNS number. UNS N07718, N09925 are listed in Tables A.31 and A.32, while UNS N07725 is listed in Table A.33 and UNS R31233 in Table A.38 of Annex A. Other CRAs not listed in these industry standards have been successfully and extensively used in oil and gas production fluids containing hydrogen sulfide, such as UNS R30006.

As noted above, the metal body 50 in the illustrated embodiment is covered with a metal layer 52. In the illustrated embodiment, the metal layer 52 comprises an alloy, preferably a metal such as a refractory metal. Refractory metals are a class of metals extraordinarily resistant to heat, wear, and corrosion. The five refractory metals are: Tungsten (W), Molybdenum (Mo), Niobium (Nb), Tantalum (Ta), and Rhenium (Re). Preferably, the metal layer 52 is comprised of tantalum. Tantalum is one of the most corrosion resistant substances available. However, a different refractory metal may be used. In the illustrated embodiment, the metal layer 52 has a greater ductility than the metal body 50. The metal layer 52 is provided to form a seal against an opposing seal surface and the metal body 50 is provided to supply structural integrity and strength for the metal layer 52. In addition, the metal layer 52 is disposed over the entire surface of the seal ring 30 in the illustrated embodiment. However, the metal layer 52 may be disposed over less than the entire surface of the seal ring 30. For example, in an alternative embodiment, the metal layer 52 may be disposed only over a sealing surface or sealing surfaces.

In this embodiment, the metal layer 52 is a tantalum alloy, such as the tantalum alloy corresponding to UNS No. R05200. Tantalum alloy R05200 is listed in Table A.42 of Annex A of NACE MR 0175 as a CRA. The environmental and material limits for alloy R05200 are provided in Table A.42, as well. As illustrated in FIG. 5, Table D.12 from Annex D of Part 3 of NACE MR 0175 provides the chemical composition of alloy R05200. The alloy is comprised of small amounts of carbon, cobalt, iron, silicon, molybdenum, tungsten, nickel, and titanium, and other elements with the remainder tantalum. However, unalloyed tantalum or another tantalum alloy may be used, such as an alloy corresponding to UNS No. R05210.

Referring generally to FIGS. 2, 3, and 3A, another portion of the wellhead assembly 20 is presented. In this portion of the wellhead assembly, a seal assembly 54 is provided to seal an annulus 56 between the wellhead 22 and a casing hanger 58. The casing hanger 58 is used to support a string of casing (not shown) from the wellhead 22.

The illustrated embodiment of the seal assembly 54 comprises a seal ring 60 and an energizing ring 62. The seal ring 60 is provided to form a seal with the high pressure wellhead 22 on one side and the casing hanger 58 on the other side, thereby sealing the annulus 56 between the wellhead 22 and the casing hanger 58. Once the casing hanger 58 and the seal assembly 54 are in position within the high pressure wellhead 22, the energizing ring 62 is used to activate the seal ring 60. The seal ring 60 has an inner leg 64 and an outer leg 66 with a slot 68 between them. When the energizing ring 62 is driven into the slot 68 of the seal ring 60, the inner leg 64 is driven against the casing hanger 58 and the outer leg 66 is driven against the high pressure wellhead 22.

The seal ring 60 has a metal body 70 with a metal layer 72 disposed over the surface of the metal body 70 in the illustrated embodiment. In the illustrated embodiment, the metal layer 72 comprises tantalum. The energizing ring 62 may also be comprised of a metal body with a metal layer disposed over the surface.

As with the seal assembly 30 above, the metal layer 72 is used to form a seal and the metal body 70 is provided to support the metal layer 72. When the inner leg 64 is driven against the casing hanger 58 and the outer leg 66 is driven against the wellhead 22, the metal layer 72 forms a seal with the wellhead 22 and with the casing hanger 58. In the illustrated embodiment, the high pressure wellhead 22 and the casing hanger 58 have wickers 74, 76, respectively, formed therein. The metal layer 72 is softer than the metal body 70 and is deformed into the wickers 74, 76 forming a seal. In addition, the metal body 70 of the illustrated seal assembly 54 is formed of a corrosion-resistant alloy (CRA), such as a nickel or cobalt alloy. The energizing ring 62 may also comprise a corrosion-resistant alloy (CRA).

Referring generally to FIGS. 4 and 4A, a swivel seal assembly is presented and represented generally by reference numeral 78. The swivel seal 78 is provided to seal the annulus 80 between an inner member 82 and an outer member 84. In the illustrated embodiment, the inner member 82 and outer member 84 have several seal pads 86 that are used to form seals with the swivel seal assembly 78. The seal assembly 78 has seal arms 88 that have seal surfaces 90 that are configured to form a seal against the seal pads 86. In this embodiment, the seal surfaces 90 have a metal layer 92 that is used to form the seal with the seal pads 86. However, the metal layer 92 may be located on the seal pads 86, rather than the seal surfaces 90 of the seal assembly 78. In the illustrated embodiment, the seal arms 88 are comprised of a corrosion-resistant material, such as a nickel or cobalt alloy. In addition, the metal layer 92 also is comprised of a corrosion-resistant material. In particular, the illustrated embodiment of the metal layer 92 can be comprised of tantalum.

While only certain features of the invention have been illustrated and described herein, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.

CLAIMS:

1. A seal assembly for a wellhead assembly, the seal assembly comprising:

a metal seal structural body comprising a corrosion-resistant alloy (CRA) having at least one seal surface area adapted to form a seal against an opposing surface of the wellhead assembly; and

a metal layer disposed directly on at least one of the seal surface areas to form a metal-to-metal seal, wherein the metal layer comprises tantalum.

2. The seal assembly as recited in claim 1, wherein the metal layer comprises an alloy corresponding to UNS (Unified Numbering System) R05200.

3. The seal assembly as recited in claim 1, wherein the metal layer comprises an alloy corresponding to UNS (Unified Numbering System) R05210.

4. The seal assembly as recited in claim 1, wherein the CRA is an alloy intended to be resistant to general and localized corrosion of oilfield environments that are corrosive to carbon steels.

5. The seal assembly as recited in any preceding claim, wherein the CRA is a nonferrous-based alloy in which any one or the sum of the specified amount of the elements titanium, nickel, cobalt, chromium, and molybdenum exceeds 50% (mass fraction).

6. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises a precipitation-hardened nickel-based alloy.

7. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises an alloy corresponding to UNS (Unified Numbering System) alloy N07718.

8. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises an alloy corresponding to UNS (Unified Numbering System) alloy N07725.

9. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises an alloy corresponding to UNS (Unified Numbering System) alloy N07716.

10. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises an alloy corresponding to UNS (Unified Numbering System) alloy N09925.

11. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises a precipitation-hardened cobalt-based alloy.

12. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises an alloy corresponding to UNS (Unified Numbering System) alloy R31233.

13. The seal assembly as recited in any one of the preceding claims, wherein the metal seal structural body comprises an alloy corresponding to UNS (Unified Numbering System) alloy R30006.

14. The seal assembly as recited in any one of the preceding claims, wherein the metal body comprises a first corrosion-resistant alloy; and wherein the metal layer comprises a second corrosion-resistant alloy, the second corrosion-resistant alloy having a greater ductility than the first corrosion-resistant alloy.

15. The seal assembly as recited in claim 14, wherein the second corrosion-resistant alloy comprises a refractory metal.

16. The seal assembly as recited in claim 15, wherein the second corrosion-resistant alloy comprises tantalum.

17. A method of manufacturing a seal, the method comprising:
machining a metal comprising a corrosion-resistant alloy (CRA) to form a base seal structure having at least one surface configured to form a seal against an opposing surface of the wellhead assembly; and

disposing a layer comprising tantalum directly on the at least one surface configured to form a seal against an opposing surface of the base seal structure or the opposing surface.

18. The method of claim 17, wherein:
the layer comprising tantalum has a greater ductility than the corrosion-resistant alloy of the base seal structure or the opposing surface.

19. A seal assembly for a wellhead assembly substantially as hereinbefore described with reference to the accompanying drawings.

20. A method substantially as hereinbefore described with reference to the accompanying drawings.