

SEAL RING BACKUP DEVICES AND METHODS FOR PREVENTING EXTRUSION**BACKGROUND**

[0001] The present invention relates to sealing systems, and more particularly, to seal ring backup devices having a scarf cut and methods of use thereof.

[0002] Preventing leakage of fluids such as liquids and gasses between sliding or turning parts of a machine often requires a sealing system that includes at least a seal ring, a seal ring backup device, and a gland designed to receive the seal ring and seal ring backup device. Common examples of seal rings and seal ring backup devices include an o-ring and an o-ring backup device, which are configured to fit into a gland. A gland may be part of a body such as a bore or a movable part such as a piston. As used herein, a "gland" is a machined cavity including a machined groove and mating surfaces into which a seal ring and/or a seal ring backup device are fitted. Within a gland, a seal ring may close the gap between mating parts, allowing a seal to form. A gland is usually made in a portion of metal or another rigid material. In order to form a proper seal, the design characteristics of a gland (*e.g.*, diameter, removable parts, contour of the cavity walls, etc.) must be compatible with the specific design considerations of the seal ring and the seal-ring backup device.

[0003] In particular, o-rings are torus, or doughnut-shaped seal rings used to provide a deformable seal for mating parts that may have gaps, among many things, due to parts fit or dimensional tolerances between parts. O-rings are usually molded from elastomers such as deformable rubber and can be found installed on the high pressure side (fluids generally flow from high pressure to low pressure) of a variety of sealed systems including valves, pump shafts, and hydraulic pistons. O-ring backup devices are ring-shaped protective elements used to support the o-rings against mechanical failure (*e.g.*, resulting from extreme deformation) and enhance the pressure rating of an o-ring seal. O-ring backup devices are typically made from relatively rigid materials and installed on the lower pressure side.

[0004] While an o-ring's primary function is to provide a seal, an o-ring backup device does not typically have any intended sealing function. Instead, an o-ring backup device is designed to remove extrusion gaps inside a gland. As used herein, "extrusion" generally refers to an extreme case of deformation where a small portion of a seal ring is forced into a small clearance gap within a cavity. As used herein, "clearance gap" generally refers to the gap between two mating surfaces. Extrusion can often lead to physical damage to a seal ring, which leads to seal failure. An o-ring backup device, by way of its design, can reduce or prevent extrusion of the o-ring by effectively closing the clearance gap within the cavity. Thus, an o-ring backup device can prolong the life span of an o-ring within a sealing system and ensure a properly working seal. Seal system pressure ratings can also be significantly increased when seal ring backup devices are used.

[0005] In a typical setup, an o-ring may be installed in a sealing system generally featuring a cylindrical surface, such as a piston and cylinder combination, a piston rod and rod guide combination, or a rotating shaft and housing combination. The gland may be machined in an exterior surface of the piston or, alternatively, in an interior surface of the cylinder (sometimes referred to as "the bore"). A proper installation requires that the o-ring fits into the gland and firmly contacts the side walls of the mating surfaces. Elevated temperatures and pressures can impose severe burden on the physical and mechanical properties of an elastomeric o-ring, increasing the tendency for extrusion. A variety of factors can cause extrusion in o-rings including, but not limited to, excessive clearances, o-ring material being too soft, improper machining of the o-ring gland, and improper size of the o-ring.

[0006] In order to prevent extrusion of the o-ring, an o-ring backup device may be installed into the gland to contact the o-ring from the low pressure side. Incoming pressure can act on the o-ring backup device, which, in turn, can expand or move too close and essentially eliminate the clearance gap within the gland cavity. This ensures that an o-ring will not extrude into the clearance gap.

[0007] While a seal ring backup device is useful and can allow softer elastomers to be used in higher pressure and temperature settings, it may not be

useful in all types of glands. For example, an open gland has removable parts that allow a seal ring backup device to easily fit into a gland cavity but, currently, it is believed that there is no known wedge type seal system that can be used in a "blind" gland. Blind gland is also referred to as a closed gland and cannot be taken apart. Extra stretch of the seal ring and seal ring backup device may be necessary when using a blind gland. Thus, a blind gland requires additional design considerations as the inner diameter of the seal ring backup device is smaller than the outer diameter of a gland into which it must fit.

SUMMARY OF THE INVENTION

[0008] The present invention relates to sealing systems, and more particularly, to seal ring backup devices having a scarf cut and methods of use thereof.

[0009] Some embodiments of the present invention provide seal ring back-up devices comprising: an annular body having an inner diameter, an outer diameter, and a scarf cut; and wherein the annular body is configured to fit a gland and engage a seal ring.

[0010] Other embodiments of the present invention provide methods comprising: providing a seal ring back-up device comprising: an annular body having an inner diameter and an outer diameter; and making a scarf cut on the annular body.

[0011] Still other embodiments of the present invention provide methods comprising: providing a seal ring back-up device comprising: an annular body having an inner diameter and an outer diameter; providing an elastomeric seal ring; making a scarf cut on the annular body; and placing the seal ring back-up device and a seal ring in a gland thereby providing a seal in a sealing application.

[0012] The features and advantages of the present invention will be readily apparent to those skilled in the art upon a reading of the description of the preferred embodiments that follows.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] The following figures are included to illustrate certain aspects of the present invention, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modification, alteration, and equivalents in form and function, as will occur to those skilled in the art and having the benefit of this disclosure.

[0014] Figures 1A-1C show different schematic views of a seal ring backup device.

[0015] Figure 2 shows a schematic drawing showing a cross-section of an embodiment of a seal ring backup device with a metallic wedge ring design.

[0016] Figures 3A-3H show cross-sectional views of various configurations for wedge shaped seal ring backup devices. Figure 3H shows the wedge shaped design used in a bonded seal.

[0017] Figures 4A-4B show cross-sectional views of two separate embodiments of a seal ring backup devices, illustrated in place in engagement with an o-ring between a piston and a bore.

[0018] Figures 5A-5B show a cross-sectional close-up view of an embodiment of a seal ring backup device without (Figure 5A) and with (Figure 5B) external pressure.

DETAILED DESCRIPTION

[0019] The present invention relates to sealing systems, and more particularly, to seal ring backup devices having a scarf cut and methods of use thereof.

[0020] The present invention provides devices and methods for supporting and protecting seal rings against damaging extrusion and mechanical failure. The seal ring backup device **100** provides enhanced protection against extrusion of an o-ring or other seal ring. Seal rings are particularly susceptible to extrusion in high temperature and/or high pressure conditions. These conditions are common in mechanical systems requiring fluidic seals in downhole applications. The seal ring backup device **100** may essentially close any extrusion gap arising from parts fit, dimensional tolerances between parts, or other sources. As a result, elastomers that traditionally lack toughness may also be used as seal rings. While these softer elastomers often have less extrusion resistance, they typically have greater temperature resistance. The features of the present invention are consistently labeled in all the figures described herein.

[0021] The seal ring backup device **100** also features a scarf cut **102** and may be configured to form a wedge **202** (illustrated in Figure 2). A scarf cut **102** is made by cutting the seal ring backup device **100** at an angle relative to both its horizontal and vertical planes (*i.e.*, at a compound angle). This wedge **202** in turn may form a wedge type seal (Figure 5) within a sealing system, thereby eliminating any extrusion gap. In the seal ring backup device **100**, the geometrical configuration (*e.g.*, angle) of the wedge **202** ensures that the seal ring backup device **100** will contact and close the clearance gap immediately and before the seal ring **300** can extrude. The scarf cut **102** also allows the seal ring backup device **100** to expand rapidly without excessive energy thus making it useful for a variety of glands including blind glands. The seal ring backup device **100** may feature any of a variety of surface geometries (Figures 3A-3H) which can accommodate a broad range of seal ring sizes, shapes, and diameters.

[0022] Figures 1A-1C show the seal ring backup device **100** in three related views. Figure 1A is a reference view in which the vertical plane is

perpendicular to the direction of fluid pressure. Pressure is labeled as P with an arrow indicating the direction of higher to lower pressure. In other words, the arrow points towards the region of lower pressure. In the embodiments shown in Figures 1A, 1B and 2, the seal ring backup device **100** is oriented so that the high pressure side is the left side of the seal ring backup device **100** while the low pressure side is the right side.

[0023] Figure 1B shows the seal ring backup device **100** after rotation about a compound angle relative to the orientation shown in Figure 1A. This view shows certain features of the seal ring backup device **100** that may be difficult to illustrate in the reference view shown in Figure 1A.

[0024] Referring to Figure 1B, the seal ring backup device **100** comprises an annular body **104** featuring a scarf cut **102**. The annular body **104** has an inner diameter **106** and an outer diameter **108**. The surface of the seal ring backup device **100** facing the center of the annular body **104** is referred to as the inner surface **114**. The surface of the seal ring backup device **100** facing outward away from the center is referred to as the outer surface **116**. The surface of the seal ring backup device **100** facing the high pressure side is referred to as the top surface **118** and may be flat or contoured. The surface of the seal ring backup device **100** facing the low pressure side is referred to as the bottom surface **120** and may be flat or contoured. While the descriptors of surfaces indicate directional orientation, they are not intended to be limiting, but are rather used for simplicity of description. Figure 1C shows a top view of the seal ring backup device **100**.

[0025] The scarf cut **102** can be created by a variety of methods, including wire Electrical Discharge Machining (EDM) cutting, sawing, milling, turning, or by any of a number of other methods for creating a slit in the annular body **104**. The scarf cut **102** is generally made on the annular body **104**, extending from the outer diameter **108** to the inner diameter **106**. The scarf cut **102** may be made at some angle θ (Figure 1B) relative to the top surface of the seal ring backup device **100**. In some embodiments, this angle θ may be from about 5 to about 45 degrees. The scarf cut **102** results in a small gap **110** and two sloped faces **112** that may interlock or slide against each other. This gap **110** provides the seal ring backup

device **100** with an inner diameter **106** that is slightly larger than the diameter of the receiving gland, thus allowing the user to easily install the seal ring backup device **100**. The gap may be on the order of about 0.001 inches to about 0.01 inches. Once the seal ring backup device **100** is installed, the gap between the scarf cut 102 may close to conceal the scarf cut **102**.

[0026] In general, the seal ring backup device **100** is constructed from a relatively rigid material compared to the seal ring **300**. Suitable examples of materials include, but are not limited to, metals, alloys, ceramics, plastics, and thermoplastics. Suitable examples of alloys include, but are not limited to, beryllium copper, bronze, brass, steel, etc. Suitable examples of plastics and thermoplastics include, but are not limited to, polyphenylene sulfide (PPS), polyaryletherketone (PAEK), amorphous polymers, polyimides (PI), polyamides (PA), and sulfones. In some embodiments, the plastic material may be cross-linked such as thermosets, true epoxies, phenolics, and cross-linked PAEK. Other suitable materials for the seal ring backup device **100** include silica, carbon black, fibers of carbon, glass, clay, polymers, nanoclay, nanotubes, and boron.

[0027] Optionally, the annular body **104** of the seal ring backup device **100** may further comprise a surface coating. Suitable coating materials include a corrosion inhibitor, a corrosion resistant material, a friction reducer, a wear reducer, and any combinations of these. Suitable examples of corrosion inhibitors include, but are not limited to, hexamine, benzotriazole, phenylenediamine, dimethylethanolamine, polyaniline, nitrites, nitrates, and cinnamaldehyde. Suitable examples of corrosion resistant material include, but are not limited to, steel, inconel, nickel-based alloys, and titanium alloys. Friction reducers suitable for use in the present invention may be polymers and/or copolymers. The term "copolymer," as used herein, is not limited to polymers comprising two types of monomeric units, but includes any combination of monomeric units, e.g., terpolymers, tetrapolymers, and the like. An example of a suitable friction reducer comprises a quaternized aminoalkyl acrylate, such as a copolymer of acrylamide and dimethylaminoethyl acrylate quaternized with benzyl chloride. Another example of a suitable friction-reducing polymer comprises acrylamide. An example

of a suitable friction reducer comprising acrylamide is a copolymer of acrylamide and acrylic acid. Such friction reducers may further comprise additional monomers, such as 2-acrylamido-2-methylpropanesulfonic acid, N,N-dimethyl acrylamide, vinylsulfonic acid, N-vinyl acetamide, N-vinyl formamide, and mixtures thereof.

[0028] Figure 2 shows a cross-section view of the seal ring backup device **100** oriented similarly (*i.e.*, pressure flows left to right) to the view shown in Figure 1A. The hatched area represents the cross-sectioned portion of the seal ring backup device **100**. In this embodiment, the top surface **118** (Figures 1B and 1C) of the seal ring backup device **100** is flat or nearly flat. Once installed, the top surface **118** should make contact with the seal ring **300**.

[0029] In some embodiments, the top surface **118** may be angled, v-ringed or u-cupped, etc. to facilitate the contact between the top surface **118** and the seal ring **300** (Figure 3H). In the embodiment shown in Figure 3H, a seal ring backup device **100** has been installed on opposing sides of the seal ring **300**. Figure 3H also represents the bonding of the seal ring backup devices to the seal ring.

[0030] Referring again to the embodiment shown in FIG. 2, the inner surface **114** is contoured as a wedge **202**. The bottom surface **120** also has a chamfered cut **200**. In some embodiments, the top surface **118** may be flat (FIG. 3A), convex (FIG. 3B), concave (FIG. 3C), angled (FIG. 3D), stepped (FIG. 3E), V-ring or U-cupped (FIG. 3G), etc. These shapes allow the seal ring backup device **100** to conform to a variety of existing seal shapes.

[0031] Figures 4A and 4B show at least two embodiments of a sealing system. Referring to Figures 4A and 4B, the seal ring backup device **100** is generally configured to fit into a gland **404** and engage a seal ring **300**. Figure 4A shows an embodiment in which the gland **404** has been machined directly onto a piston rod **402**. Alternatively, Figure 4B shows an embodiment in which the gland **404** has been machined onto the bore **400**.

[0032] Figures 5A-5B show two separate cross-sectional views related to the embodiment shown in Figure 4A. Figure 5A shows the sealing system in a non-sealed state where there is no pressure difference inside the gland. Figure 5B

shows the sealing system in a sealed state in which the seal ring **300** and the seal ring backup device **100** are subject to a difference in pressure. Under external pressure, the seal ring **300** slides the seal ring backup device **100** up against the wall **502** of the gland cavity thereby closing the extrusion gap **500**. It may also be desirable for the wall **502** of the gland **404** to be wedge shaped. The angle α_R of the seal ring backup device **100** and the angle α_g of the gland wall **502** may be configured so that the sum angle is about 90 degrees. The angle α_R refers to the angle relative to a plane passing perpendicular to a centerline of the piston and the seal ring backup device **100**. The angle α_g refers to the angle relative to a plane passing horizontal to a centerline of the piston and the wall **502** of the gland **404**. In some embodiments, it is desirable that both angles α_R and α_g are about 45 degrees. In some embodiments, it is desirable that angles α_R and α_g are slightly mismatched. In a non-limiting example, angle α_R may be designed to be about 44.5 degrees – 0.5 degree +0 degrees and angle α_g may be designed to be about 45.0 degrees +0 degree and -0.5 degree.

[0033] Therefore, the present invention is well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the present invention may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope and spirit of the present invention. The invention illustratively disclosed herein suitably may be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of “comprising,” “containing,” or “including” various components or steps, the compositions and methods can also “consist essentially of” or “consist of” the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a

lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the element that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

CLAIMS

1. A seal ring back-up device, comprising:

A solitary annular body having a top surface, a bottom surface opposite the top surface, an inner surface, and an outer surface opposite the inner surface, wherein the inner surface defines an inner diameter of the annular body and the outer surface defines an outer diameter of the annular body; and

a scarf cut extending between the inner and outer surfaces of the annular body and defining a gap in the annular body that extends completely between the top surface and the bottom surface, the gap being defined at an angle relative to the top surface,

wherein the annular body is arrangeable within a gland and the top surface is directly engageable with a seal ring, and

wherein the top surface comprises a surface contour shape selected from the group consisting of convex, stepped at the outer surface, chamfered at the outer surface, and any combination thereof.
2. The seal ring back-up device of claim 1, wherein the scarf cut provides opposing sloped faces each angled at the angle relative to the top surface.
3. The seal ring back-up device of claim 1, wherein the bottom surface is wedge shaped.
4. The seal ring back-up device of claim 1, wherein the surface contour shape is concave to receive the seal ring.
5. The seal ring back-up device of claim 1, wherein the annular body comprises a material selected from the group consisting of a metal, a metal alloy, a plastic, an amorphous polymer, glass, clay, ceramic, a thermoset, an epoxy, silica, carbon black, carbon fibers, nanoclay, nanotubes, boron, and any combination thereof.
6. The seal ring back-up device of claim 1, wherein the annular body comprises a material selected from the group consisting of polyphenylene sulfide, polyaryletherketone, an amorphous polymer, a polyimide, a polyamide, a sulfone, any derivative thereof, and any combination thereof.
7. The seal ring back-up device of claim 1, further comprising a surface coating disposed on the annular body, the surface coating being selected from the group consisting of a corrosion inhibitor, a corrosion resistant material, a friction reducer, a wear reducer, ceramic, and any combination thereof.
8. A sealing system, comprising:

a bore;

a piston extendable within the bore and thereby defining an extrusion gap between the bore and the piston;

a gland defined in at least one of the bore and the piston and providing a wall;
a seal ring arranged within the gland; and in direct contact with the seal ring, the seal ring back-up device comprising:
a solitary annular body having a top surface, engageable with the seal ring, a bottom surface opposite the top surface, and engageable with the wall, an inner surface, and an outer surface opposite the inner surface; and
a scarf cut extending between the inner and outer surfaces of the annular body and defining a gap in the annular body that extends completely between the top surface and the bottom surface, the gap being defined at an angle relative to the top surface.

9. The sealing system of claim 8, wherein the scarf cut provides opposing sloped faces each angled at the angle relative to the top surface, the opposing sloped faces being slidably engageable with one another during operation.

10. The sealing system of claim 8, wherein the bottom surface and the wall are each wedge shaped.

11. The sealing system of claim 8, wherein the top surface comprises a surface contour shape selected from the group consisting of flat, convex, concave, angled, stepped at the outer surface, chamfered at the outer surface, and any combination thereof.

12. The sealing system of claim 8, wherein the annular body comprises a material selected from the group consisting of a metal, a metal alloy, a plastic, an amorphous polymer, glass, clay, ceramic, a thermoset, an epoxy, silica, carbon black, carbon fibers, nanoclay, nanotubes, boron, polyphenylene sulfide, polyaryletherketone, an amorphous polymer, a polyimide, a polyamide, a sulfone, any derivative thereof, and any combination thereof.

13. The sealing system of claim 8, further comprising a surface coating disposed on the annular body, the surface coating being selected from the group consisting of a corrosion inhibitor, a corrosion resistant material, a friction reducer, a wear reducer, ceramic, and any combination thereof.

14. The sealing system of claim 8, wherein the seal ring is bonded to the seal ring back-up device.

15. A method, comprising:

arranging a seal ring within a gland defined within one of a bore and a piston, the piston being extendable within the bore and thereby defining an extrusion gap between the bore and the piston;

arranging a seal ring back-up device within the gland and in direct contact with the seal ring, the seal ring back-up device comprising

a solitary annular body having a top surface, a bottom surface opposite the top surface, an

inner surface, and an outer surface opposite the inner surface, and

a scarf cut extending between the inner and outer surfaces of the annular body and defining a gap in the annular body that extends completely between the top surface and the bottom surface, the gap being defined at an angle relative to the top surface;

forcing the seal ring against the top surface as an external pressure increases and thereby forcing the bottom surface against a wall defined in the gland; and

closing the extrusion gap with the seal ring back-up device as the bottom surface is forced against the wall defined and thereby preventing the seal ring from deforming into the extrusion gap.

16. The method of claim 15, wherein the scarf cut provides opposing sloped faces each angled at the angle relative to the top surface, and wherein arranging the seal ring back-up device within the gland comprises:

separating the opposing sloped faces to increase an inner diameter of the seal ring back-up device; and

extending the piston through the seal ring back-up device until the seal ring back-up device locates the gland.

17. The method of claim 15, wherein the scarf cut provides opposing sloped faces each angled at the angle relative to the top surface, and wherein closing the extrusion gap with the seal ring back-up device comprises slidingly engaging the opposing sloped faces on one another.

18. The method system of claim 15, wherein the bottom surface and the wall are each wedge shaped and forcing the bottom surface against the wall comprises slidingly engaging the bottom surface against the wall.

19. The method of claim 15, wherein forcing the seal ring against the top surface comprises forcing the seal ring against a surface contour shape provided on the top surface, the surface contour shape being selected from the group consisting of flat, convex, concave, angled, stepped at the outer surface, chamfered at the outer surface, and any combination thereof.

20. The method of claim 15, wherein arranging the seal ring back-up device within the gland is preceded by coating the annular body with a surface coating selected from the group consisting of a corrosion inhibitor, a corrosion resistant material, a friction reducer, a wear reducer, ceramic, and any combination thereof.