

EXPANDABLE SEAL

TECHNICAL FIELD

The present disclosure relates generally to operations performed and equipment used in conjunction with a subterranean well, such as a well for recovery of oil, gas, or minerals. More particularly, the disclosure relates to reusable expandable seals for downhole applications.

BACKGROUND

In the course of drilling, completing, or servicing a subterranean well for hydrocarbon production, one or more seals, or packers, may be installed in the wellbore to isolate one zone from another. A seal may be run into a wellbore via wireline, slick line, coiled tubing, drill string, or another conveyance, and then radially expanded into sealing engagement with the interior surface of a casing, liner, or other tubular member.

Expandable seals must be able to operate against increasingly higher pressures and axial forces. Differential pressures across a seal may reach up to 15,000 psi.

Resilient materials such as rubber, which can readily be axially compressed to cause their diameters to expand, tend to have very low pressure holding capabilities due to the tendency of the resilient material to axially extrude into an extrusion gap under a differential pressure. These types of sealing mechanisms usually require structural extrusion limiters to reduce the extrusion gap. Moreover, reusable resilient seals may become subject to damaged sealing surfaces, referred to as nibbling, in which small edge portions of the sealing element become detached over repeated uses.

Recently, dissolving frac plugs have been commercialized. Currently dissolving elastomeric elements used on dissolving frac plugs tend to dissolve too slowly at temperatures below 200F. Metallic dissolving materials dissolve more quickly below 200F. In dissolving frac plug applications, the use of metallic seal made from the dissolving metal alloys may improve full dissolution of the frac plug below 200F. The dissolving metallic alloys also dissolve into solution and do not reform at cooler temperatures. Currently dissolving rubber or rubber-like elements do not completely dissolve into solution; rather they flake apart into particles and chunks. Certain types may also break down to consistency of low torque grease or syrup, and in some cases these types of materials can reform as solids at the cooler temperatures that occur near the surface of the wellbore. Particles, chunks, low torque grease, syrup, or reformed solid chunks flowing through wellhead or surface equipment may create restrictions and clogs. The dissolving metallic alloys reduce this risk, because they dissolve more fully into solution.

A metallic circular seal may also be radially expanded to form a seal, which may be operable under a higher differential pressure than a resilient member and less prone to nibbling effects. However, the expansion process to a larger diameter introduces internal stresses in the sealing element. The outer diameter fibers of the seal will require a growth in length, which creates geometry and stress challenges when using metallic materials. Such stresses may cause a metallic seal to become plastically deformed and therefore not able to retract when desired.

Accordingly, when designing a seal, materials and/or geometries that allow high expansion with acceptable stresses tend to sacrifice the strength and pressure holding capabilities.

For many oil and gas applications, a perfect seal is not required. A metallic circular seal that is radially expanded may prevent majority of flow and meet the application needs. In many applications, the fluid media itself may bridge seal imperfections, and in doing so, provide a full seal. For example, many hydraulic fracturing applications include sand in the fluid media. Sand and gel-like fluids used in the hydraulic fracturing media are known to bridge and block seal imperfections.

SUMMARY

According to a first aspect of the present invention, there is provided an apparatus for sealing against an interior surface of a cylindrical tubular member, comprising: a metallic ring defining an axis, an uphole end, a downhole end, an inner circumferential surface, and an outer circumferential surface, said ring characterized by a uniform axial cross-sectional profile having an outward-facing convexity and an inward-facing concavity; a first plurality of slits radially formed through said ring about said outer surface; a circular resilient gasket at least partially coaxially disposed within said concavity; an uphole shoulder abutting said uphole end of said ring; and a downhole shoulder abutting said downhole end of said ring and axially movable with respect to said uphole shoulder so as to selectively axially compress and radially expand said ring.

According to a second aspect of the present invention, there is provided a method for sealing against an interior surface of a cylindrical tubular member, comprising: providing an apparatus including a metallic ring characterized by a uniform axial cross-sectional profile with an outward-facing convexity and an inward-facing concavity, a first plurality of slits radially formed through said ring about an outer surface of said ring, and a circular resilient gasket at least partially coaxially disposed within said concavity; disposing said apparatus within said tubular member; and selectively axially compressing an uphole end of said ring with respect to a downhole end of said ring so as to radially expand said ring into sealing engagement with said interior surface of said tubular member.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments are described in detail hereinafter with reference to the accompanying figures, in which:

Figure 1 is a block-level schematic diagram of an exemplary wireline system, showing a wireline tool suspended by wireline with an apparatus for sealing against an interior surface of a cylindrical tubular member, according to an embodiment;

Figure 2 is an elevation view in partial cross section of an exemplary drilling, completion, workover system or the like, showing a rig carrying a string and a downhole tool with an apparatus for sealing against an interior surface of a cylindrical tubular member, according to an embodiment;

CLAIMS

1. An apparatus for sealing against an interior surface of a cylindrical tubular member, comprising:

a metallic ring defining an axis, an uphole end, a downhole end, an inner circumferential surface, and an outer circumferential surface, said ring characterized by a uniform axial cross-sectional profile having an outward-facing convexity and an inward-facing concavity;

a first plurality of slits radially formed through said ring about said outer surface;

a circular resilient gasket at least partially coaxially disposed within said concavity;

an uphole shoulder abutting said uphole end of said ring; and

a downhole shoulder abutting said downhole end of said ring and axially movable with respect to said uphole shoulder so as to selectively axially compress and radially expand said ring.

2. The apparatus of claim 1 further comprising:

said first plurality of slits radially formed through said ring about said outer surface at least partially between said convexity and said uphole end; and

a second plurality of slits radially formed through said ring about said outer surface at least partially between said convexity and said downhole end.

3. The apparatus of claim 2 wherein:

said second plurality of slits is circumferentially alternated between said first plurality of slits.

4. The apparatus of claim 1 further comprising:

a base coaxially disposed within said ring and forming one of said uphole shoulder and said downhole shoulder; and

a sleeve coaxially and axially movably carried by said base and forming the other of said uphole shoulder and said downhole shoulder.

5. The apparatus of claim 1 further comprising at least one of:

an actuator coupled between said uphole shoulder and said downhole shoulder;

a circular stiffener at least partially coaxially disposed within said concavity, said resilient gasket sandwiched between said ring and said stiffener;

a resilient material filling said first plurality of slits; and

a coating of resilient material formed about said outer surface.

6. The apparatus of claim 5 wherein:

said stiffener is characterized by a generally triangular axial cross-sectional profile.

7. The apparatus of claim 2 further comprising:

a resilient material filling said first and second pluralities of slits.

8. A method for sealing against an interior surface of a cylindrical tubular member, comprising:

providing an apparatus including a metallic ring characterized by a uniform axial cross-sectional profile with an outward-facing convexity and an inward-facing concavity, a first plurality of slits radially formed through said ring about an outer surface of said ring, and a circular resilient gasket at least partially coaxially disposed within said concavity;

disposing said apparatus within said tubular member; and

selectively axially compressing an uphole end of said ring with respect to a downhole end of said ring so as to radially expand said ring into sealing engagement with said interior surface of said tubular member.

9. The method of claim 8 further comprising at least one of:

reducing stress within said ring during radial expansion of said ring by said first plurality of slits;

selectively operating an actuator to axially compress and radially expand said ring;

supporting said resilient gasket by a circular stiffener at least partially coaxially disposed within said concavity, said resilient gasket sandwiched between said ring and said stiffener; and

filling said first plurality of slits with a resilient material.

10. The method of claim 8 further comprising:

radially forming said first plurality of slits through said ring about said outer surface at least partially between said convexity and said uphole end;

radially forming a second plurality of slits through said ring about said outer surface at least partially between said convexity and said downhole end; and

circumferentially alternating said second plurality of slits between said first plurality of slits to reduce expansion of said circular gasket into said first and second pluralities of slits during radial expansion of said ring.

11. The method of claim 8 further comprising:

coaxially carrying said ring about a base, said base forming one of an uphole shoulder disposed adjacent said uphole end of said ring and a downhole shoulder disposed adjacent said downhole end of said ring;

coaxially carrying a sleeve about said base, said sleeve forming the other of said uphole shoulder and said downhole shoulder; and

selectively axially moving said sleeve with respect to said base to axially compress and radially expand said ring.

12. The method of claim 8 further comprising:

coating said outer surface of said ring with a resilient material; and

radially expand said ring to bring said resilient material into sealing engagement with said interior surface of said tubular member.