COMPOSITE DOWNHOLE TOOL WITH REDUCED SLIP VOLUME

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Filed:    Jul. 9, 2009

Abstract
A single bidirectional slip for a downhole tool reduces the volume of metal and allows an increased drill up speed. A dual sealing element system, with one sealing element above and one below the bi-directional slip, provides boost forces going through the sealing elements to the slip. The wickers of the slip can be separated by a substantially flat circumference section for placing a band around the slip to improve fracturing uniformity. The wickers can have any of a variety of configurations, including orientations axially away from the central portion of the slip and orientations axially toward the central portion of the slip.
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TECHNICAL FIELD

[0001] The present invention relates to the field of downhole tools, and in particular to downhole tools such as bridge plugs, frac-plugs, and packers.

BACKGROUND ART

[0002] An oil or gas well includes a wellbore extending into a well to some depth below the surface. Typically, the wellbore is lined with tubulars or casing to strengthen the walls of the borehole. To strengthen the walls of the borehole further, the annular area formed between the casing and the borehole is typically filled with cement to set the casing permanently in the wellbore. Perforating the casing allows production fluid to enter the wellbore and flow to the surface of the well.

[0003] Downhole tools with sealing elements are placed within the wellbore to isolate the production fluid or to manage production fluid flow through the well. For example, a bridge plug or frac-plug placed within the wellbore can isolate upper and lower sections of production zones. Bridge plugs and frac-plugs create a pressure seal in the wellbore to allow pressurized fluids or solids to treat an isolated formation.

[0004] Packers are typically used to seal an annular area formed between two co-axially disposed tubulars within a wellbore. For example, packers may seal an annulus formed between production tubing disposed within wellbore casing. Alternatively, packers may seal an annulus between the outside of a tubular and an unlined borehole. Routine uses of packers include the protection of casing from pressure, both well and stimulation pressures, as well as the protection of the wellbore casing from corrosive fluids. Other common uses include the isolation of formations or leaks within a wellbore casing or multiple producing zones, thereby preventing the migration of fluid between zones. Packers may also be used to hold kill fluids or treating fluids within the casing annulus.

[0005] The downhole tools are usually constructed of cast iron, aluminum, or other alloyed metals, but can be made of non-metallic materials, such as composite materials. A sealing member is typically made of a composite or synthetic rubber malleable material that seals off an annulus within the wellbore to prevent the passage of fluids. The sealing member is compressed or swells, thereby expanding radially outward from the tool to engage and seal with a surrounding tubular. Conventional bridge plugs, frac plugs, and packers typically comprise a synthetic sealing member located between upper and lower metallic retaining rings, commonly known as slips, that prevent the downhole tool from moving up or down in the wellbore.

[0006] One problem associated with conventional element systems of downhole tools arises when the tool is no longer needed to seal an annulus and must be removed from the wellbore. For example, plugs and packers are sometimes intended to be temporary and must be removed to access the wellbore. Rather than de-actuate the tool and bring it to the surface of the well, the tool is typically destroyed with a rotating milling or drilling device. As the mill contacts the tool, the tool is "drilled up" or reduced to small pieces that are either washed out of the wellbore or simply left at the bottom of the wellbore. The more metal parts making up the tool, the longer the milling operation takes. Metallic components also typically require numerous trips in and out of the wellbore to replace worn out mills or drill bits.

[0007] Slips have been designed to reduce the amount of metal to reduce drill up time. Although some have attempted to create composite material slips, often pressure holding at temperature has been sacrificed to gain up drill up speed.

SUMMARY OF INVENTION

[0008] The conventional two slips of a downhole tool are combined into a single bi-directional slip, thereby reducing the volume of metal and allowing an increased drill up speed. A dual sealing element system, with one sealing element above and one below the bidirectional slip, provides boost forces going through the sealing elements to the slip. In some embodiments, teeth sections of the slip are separated by a substantially flat circumference section for placing a band around the slip to improve fracturing uniformity. The teeth sections can have any of a variety of configurations, including orientations axially away from the central portion of the slip and orientations axially toward the central portion of the slip.

BRIEF DESCRIPTION OF DRAWINGS

[0009] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate an implementation of apparatus and methods consistent with the present invention and, together with the detailed description, serve to explain advantages and principles consistent with the invention. In the drawings,

[0010] FIG. 1 is a cutaway view of a bridge plug according to the prior art;

[0011] FIG. 2 is a cutaway view of a bridge plug according to one embodiment;

[0012] FIG. 3 is a cutaway view of a bi-directional slip according to one embodiment;

[0013] FIG. 4 is a cross-sectional view of a bi-directional slip according to another embodiment; and

[0014] FIG. 5 is a cross-sectional view of a bi-directional slip according to yet another embodiment.

DESCRIPTION OF EMBODIMENTS

[0015] FIG. 1 is a cutaway view of a conventional bridge plug 100 according to the prior art. The bridge plug 100 comprises a mandrel 110, about which are disposed various elements, which are typically formed of metal, but can be made of a composite material, such as is described in U.S. Pat. No. 7,124,831, which is incorporated herein by reference in its entirety for all purposes. Even when most of the bridge plug 100 is made of composite materials, the two slips 130 are typically made of metal, such as a ductile cast iron.

[0016] As shown in FIG. 1, a sealing member 120 and other related elements 125 are disposed about the mandrel 110. Axial force through the slips 130 and the other elements 125 compress the sealing member 120, causing it to expand and to seal with the surrounding tubular (not shown). The two slips 130, oriented opposite to each other, expand to engage with the surrounding tubular and help retain the downhole tool in place in the wellbore. Boost forces from the sealing member 120 on the slips 130 increase their holding ability. As described above, the two slips 130 are made of metal, typically a ductile cast iron, and increase the mill up time of the downhole tool 100.

[0017] Turning to FIG. 2, a cutaway view illustrates an improved downhole tool 200 that uses a single bidirectional
slip with reduced metal volume, allowing faster mill up time, but providing sufficient retaining ability against uphole and downhole forces when engaged with the surrounding tubular. Instead of confining a single sealing member 220 with two slips 130, in this embodiment, a single slip 210 is confined by two sealing systems 220, as described in detail below. The downhole tool 200 can be configured as a bridge plug, a frac plug, a packer, or any other desired downhole tool.

As with the conventional downhole tool 100, the downhole tool 200 uses a mandrel 110, disposing the remainder of the downhole tool 200 about the mandrel 110. Although shown in FIG. 2 as a hollow core mandrel 110, the mandrel 110 can be a solid core mandrel or can be a hollow core mandrel that is plugged with a core plug (not shown in FIG. 2) as desired. Most of the downhole tool 200, including the mandrel 110 and the sealing systems 220, is typically non-metallic, and the non-metallic elements are usually manufactured from one or more composite materials.

Instead of two unidirectional slips 130, each of which resists movement in a single axial direction and tends to disengage from the surrounding tubular in the opposite axial direction, the embodiment illustrated in FIG. 2 uses a single bi-directional slip 210 that resists movement in either axial direction once activated by the sealing systems 220 to engage with the surrounding tubular. Although made of metal, such as a ductile cast iron, the single slip 210 contains less metal than the conventional pair of slips 130.

To provide sealing with the tubular, the downhole tool 200 uses two sealing systems 220, one axially on either end of the slip 210. Each sealing system 220, in addition to sealing the downhole tool 200 with the surrounding tubular, also provides boost forces to the slip 210, increasing its ability to engage with the tubular and hold the downhole tool 200 in place under high pressure.

Each sealing system 220 includes a sealing member 225, which is a malleable, synthetic element. The sealing member 225 can have any desired configuration to seal an annulus within the wellbore. For example, the sealing member 225 can include grooves, ridges, indentations, or protrusions designed to allow the sealing member 225 to conform to variations in the shape of the interior of the surrounding tubular. The sealing member is capable in one embodiment of withstanding temperatures of 232°C (450°F) and pressure differentials of up to 103,000 kPa (15,000 psi). Other temperature and pressure configurations can be used, as well.

As illustrated in FIG. 2, according to one embodiment each sealing system 220 comprises, in addition to the sealing member 225, a cone 221 and two each of cones 224, expansion rings 223, and support rings 222. In other embodiments, a second cone 221 is also included. In the embodiment illustrated in FIG. 2, axial force is applied to the sealing system distal to the slip 210 by either a mule shoe 250 or a setting ring 240 and a setting tool (not shown), as described below. In the embodiment with a second cone 221, the additional cone 221 is interposed between the setting ring 240 and support ring 230. Such an embodiment would allow manufacture of a sealing system 220 that could be used unchanged both in downhole tools such as the downhole tool of FIG. 2 and also in conventional downhole tools such as illustrated in FIG. 1.

The sealing system 220, as illustrated in FIG. 2, transfers axial force onto the sealing member 225, compressing the sealing member 225 and thereby sealing with the surrounding tubular. Each cone 224 transfers axial force from the rest of the sealing system 220 onto the sealing member 225, compressing the sealing member 225, and causing the sealing member 225 to expand radially toward the inner surface of the surrounding tubular, sealing with the surrounding tubular.

The expansion ring 223 flows and expands in one embodiment across a tapered surface of the cone 224, applying a collapse load through the cone 224 on the mandrel 110, which helps prevent slippage of the system 220 once activated. The collapse load also prevents the cone 224 and sealing member 225 from rotating when milling up the downhole tool 200, reducing the mill up time. The cone 224 thus transfers axial force from the expansion ring 223 to the sealing member 225 to cause radial expansion of the sealing member 225.

The support ring 222 transfers axial force to the expansion ring 223. In one embodiment, the support ring 222 comprises sections that are designed to hinge radially outwardly, toward the surrounding tubular as sections are forced across a tapered section of the expansion ring 223. At full deployment, the sections expand outwardly sufficient to engage the surrounding tubular.

The cone 221 transfers axial force to the support ring 222, forcing it across the expansion ring 223 and causing the support ring 222 to expand as described above. The cone 221 proximal to the slip 210 in turn receives axial force in the opposite direction, and transfers boost force to the end of the slip 210.

The mule shoe 250 is positioned on the downhole end of the downhole tool 200, and is typically threadedly attached to the mandrel 110. The mule shoe 250 is typically pinned in position on the mandrel 110.

The setting ring 240 is an annular member that provides a substantially flat surface for use with a setting tool (not shown), and transfers axial force from the setting tool to the sealing system 220 through the other elements of the sealing system 220. In one embodiment, the support ring 230 has an outer diameter less than the outer diameter of the setting ring 240, providing a shoulder for engagement with the setting tool, which thus slips over the support ring 240 to engage with the shoulder of the setting ring 240 to transfer force from the setting tool to the sealing system 220.

The downhole tool 200 can be installed in a wellbore with any desired non-rigid system, such as electric wireline or coiled tubing. A setting tool, such as a Baker E-4 Wireline Setting Assembly commercially available from Baker Hughes, Inc., connects to an upper portion of the mandrel 110. Specifically, an outer movable portion of the setting tool is disposed about the outer diameter of the support ring 230, butting the first end of the setting ring 240. An inner portion of the setting tool is fastened about the outer diameter of the support ring 230. The setting tool and downhole tool 200 are then run into the well casing to the desired depth where the downhole tool 200 is to be installed.

To set or activate the downhole tool 200, the mandrel 110 is held by the wireline, through the inner portion of the setting tool, as an axial force is applied through the outer movable portion of the setting tool to the setting ring 240. The axial forces cause the outer portions of the downhole tool 200 to move axially relative to the mandrel 110.

The force asserted against the setting ring 240 is transmitted by the setting ring 240. An equal and opposite force is asserted by the stationary mule shoe 250 on the other end of the downhole tool 200. The force from both ends is transmitted to the sealing systems 220, which causes the
sealing members 225 to expand and to seal with the surrounding tubular. The force is further transmitted to the slip 210, activating each end of the slip 210 by causing each end of the slip 210 to expand and to engage with the surrounding tubular, setting the slip 210 and thus the downhole tool as a whole.

An alternate embodiment is shown in FIG. 5. As in the embodiment of FIG. 4, the teeth sections 510 and 530 comprise simple triangular teeth separated by a central section 520 for the attachment of the band 340. The orientation of the teeth 510 and 530 are reversed from the orientation of the teeth 410 and 430, so that the teeth are oriented toward the central portion 520.

An alternate embodiment is shown in FIG. 5. As in the embodiment of FIG. 4, the teeth sections 510 and 530 comprise simple triangular teeth separated by a central section 520 for the attachment of the band 340. The orientation of the teeth 510 and 530 are reversed from the orientation of the teeth 410 and 430, so that the teeth are oriented toward the central portion 520.

The number, shape, and configuration of teeth illustrated in FIGS. 2-5 are illustrative and by way of example only, and any number, shape, and configuration of teeth can be used as desired, including orientation axially either toward the ends of the slip or toward the center. The use of wickers or teeth is illustrative and by way of example only. In some embodiments, other surface treatments other than wickers or teeth can be used to provide gripping ability for the slip.

The bi-directional slip and dual sealing systems described herein may be used in conjunction with any downhole tool used for sealing an annulus within a wellbore, such as frac-plugs, bridge plugs, or packers, for example.

In conclusion, by using a single bidirectional slip surrounded by two sealing systems, various embodiments provide a downhole tool with reduced metal content, allowing faster mill up and less metal waste to fall downhole, but without sacrificing the ability to hold the downhole tool in place under high temperature and pressure conditions. The two sealing systems, in addition to doubly sealing with the surrounding tubular, provide boost force on the single slip in both directions, thus increasing the holding power of the single slip.

While certain exemplary embodiments have been described in detail and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not devised without departing from the basic scope thereof, which is determined by the claims that follow.

We claim:
1. A downhole tool for insertion into a tubular, comprising:
   a non-metallic mandrel;
   a bi-directional slip, disposed about an axis of the mandrel and configured to resist axial movement in either direction when activated;
   a pair of non-metallic sealing systems, each capable of sealing with the tubular, activating a portion of the bi-directional slip, and disposed about the axis of the mandrel at opposite ends of the bi-directional slip.
2. The downhole tool of claim 1, wherein each of the pair of non-metallic sealing systems comprises:
   a sealing member, configured to expand radially upon the application of axial force on the sealing member; and
   a pair of non-metallic element systems, disposed with opposite ends of the sealing member, configured to compress the sealing member upon the application of axial force on the element systems and to activate a portion of the bi-directional slip.
3. A downhole tool of claim 1, wherein each of the pair of sealing systems comprises:
   a compressible sealing member, disposed about the mandrel and configured to expand radially when compressed;
   a non-metallic sealing element system, disposed about the mandrel between the sealing member and the slip, comprising:
   a first cone, disposed adjacent to the sealing member; a support ring;
an expansion ring; disposed between the first cone and the support ring; a second cone, disposed between the support ring and the bi-directional slip, configured to activate an end of the slip.

4. The downhole tool of claim 1, wherein the slip comprises: a first section, configured to resist axial movement in first direction when activated; and a second section, configured to resist axial movement in a second direction when activated, the second direction opposite the first direction.

5. The downhole tool of claim 1, wherein the slip comprises: a first section, configured to resist axial movement in first direction when activated; a second section, configured to resist axial movement in a second direction when activated, the second direction opposite the first direction; and a third section, disposed between the first section and the second section.

6. The downhole tool of claim 5, wherein the slip further comprises: a band disposed about the third section.

7. The downhole tool of claim 1, wherein the slip comprises: a first plurality of wickers, configured to resist axial movement of the slip in a first direction when any of the first plurality of wickers are engaged with an inner surface of the tubular; and a second plurality of wickers, disposed with the first plurality of wickers and configured to resist axial movement of the slip in a second direction, opposite the first direction, when any of the second plurality of wickers are engaged with the inner surface of the tubular.

8. The downhole tool of claim 1, wherein the downhole tool is a frac plug.

9. The downhole tool of claim 1, wherein the downhole tool is bridge plug.

10. The downhole tool of claim 1, wherein the downhole tool is a packer.

11. A method of setting a downhole tool in a tubular, comprising: positioning the downhole tool at a desired location in the tubular; expanding a first portion of a bidirectional slip of the downhole tool with a first sealing system of the downhole tool; expanding a second portion of a bidirectional slip of the downhole tool with a second sealing system of the downhole tool; engaging the first portion of the bi-directional slip with the tubular; and engaging the second portion of the bidirectional slip with the tubular, wherein the first portion of the slip is configured to resist movement along a central axis of the downhole tool in a first direction when engaged with the tubular, and wherein the second portion of the slip is configured to resist movement along the central axis of the downhole tool in a second direction, opposite the first direction, when engaged with the tubular.

12. The method of claim 11, wherein expanding a first portion of a bidirectional slip of the downhole tool over a first sealing system of the downhole tool comprises: sealing the first sealing system with the tubular; driving a conical element of the first sealing system into the first portion of the slip; fracturing the first portion of the slip along a predetermined fracture zone; and expanding the fractured first portion of the slip over a surface of the conical element.

13. The method of claim 11, further comprising: sealing the second sealing system with the tubular; driving a conical element of the second sealing system into the second portion of the slip; fracturing the second portion of the slip along a predetermined fracture zone; and expanding the fractured second portion of the slip over a surface of the conical element of the second sealing system.

14. The method of claim 11, wherein the first direction is toward the second portion of the slip, and the second direction is toward the first portion of the slip.

15. The method of claim 11, wherein the first direction is away from the second portion of the slip and the second direction is away from the first portion of the slip.

16. A system for setting a downhole tool having a mandrel in a tubular, comprising: a bi-directional slip, disposed about an axis of the mandrel and configured to resist axial movement in either direction when activated; a pair of non-metallic element systems, each capable of activating a portion of the bi-directional slip and disposed about the axis of the mandrel at opposite ends of the bi-directional slip.

17. The system of claim 16, wherein each of the pair of non-metallic element systems comprises: a sealing member, configured to expand radially to seal with the tubular when compressed axially; and a pair of non-metallic element subsystems, disposed with opposite ends of the sealing member, configured to compress the sealing member upon the application of axial force on the non-metallic element subsystems.

18. The system of claim 16, wherein each of the pair of non-metallic element systems comprises: a compressible sealing member, configured to expand radially when compressed; a non-metallic sealing element subsystem, disposed coaxially between the sealing member and the slip, comprising: a first non-metallic cone, disposed adjacent to the sealing member; a non-metallic support ring; a non-metallic expansion ring; disposed between the first non-metallic cone and the non-metallic support ring; a second non-metallic cone, disposed between the non-metallic support ring and the bi-directional slip, configured to activate an end of the slip.

19. The system of claim 16, wherein the slip comprises: a first plurality of wickers, configured to resist axial movement of the slip in a first direction when any of the first plurality of wickers are engaged with an inner surface of the tubular; and a second plurality of wickers, disposed with the first plurality of wickers and configured to resist axial movement of the slip in a second direction, opposite the first direc-
tion, when any of the second plurality of wickers are engaged with the inner surface of the tubular.

20. The system of claim 16, wherein the slip comprises: a first plurality of wickers, configured to resist axial movement of the slip in a first direction when any of the first plurality of wickers are engaged with an inner surface of the tubular; and a second plurality of wickers, disposed with the first plurality of wickers and configured to resist axial movement of the slip in a second direction, opposite the first direction, when any of the second plurality of wickers are engaged with the inner surface of the tubular.

A band disposed about a central portion of the slip, between the first plurality of wickers and the second plurality of wickers.

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