Abstract: Slip segments with a friction medium are used to anchor a downhole tool in a well. Each slip segment has a slip segment body made of a drillable material. A friction medium is applied to the outer surface of the slip segment body so that the outer surface of the slip segment has an increased holding capability in the well.
DOWNHOLE TOOL WITH SLIP ELEMENTS HAVING A FRICTION SURFACE

BACKGROUND

[0001] Downhole tools for use in oil and gas wellbores often have drillable components made from metallic or non-metallic materials, such as soft steel, cast iron, engineering grade plastics, and composite materials.

[0002] In the drilling or reworking of oil wells, a great variety of downhole tools are used. For example, but not by way of limitation, it is often desirable to seal tubing or other pipe in the casing of the well, such as when it is desired to pump cement or other slurry down the tubing and force the slurry out into a formation. It thus becomes necessary to seal the tubing with respect to the well casing and to prevent the fluid pressure of the slurry from lifting the tubing out of the well. Downhole tools referred to as packers and bridge plugs are designed for these general purposes and are well known in the art of producing oil and gas.

[0003] Bridge plugs isolate the portion of the well below the bridge plug from the portion thereabove. Bridge plugs therefore may experience a high differential pressure and must be capable of withstanding the pressure so that the bridge plug seals the well and does not move in the well after it has been set.

[0004] Bridge plugs make use of metallic or non-metallic slip segments, or slips, that are initially retained in close proximity to a mandrel but are forced outwardly away from the mandrel of the tool upon the tool being set to engage a casing previously installed within an open wellbore. Upon the tool being positioned at the desired depth, or position, the slips are forced outwardly against the inside of the casing to secure the packer, or bridge plug as the case may be, so that the tool will not move relative to the casing when, for example,
operations are being conducted for tests, to stimulate production of the well, or to plug all or a portion of the well.

[0005] Cylindrically shaped inserts, or buttons, may be placed in such slip segments, especially when the slip segments are made of a non-metallic material such as plastic composite material, to enhance the ability of the slip segments to engage the well casing. The buttons must be of sufficient hardness to be able to partially penetrate, or bite into, the surface of the well casing which is typically steel. However, especially in the case of downhole tools being constructed of materials that lend themselves to being easily drilled from the wellbore once a given operation involving the tool has been performed, the buttons must not be so hard or so tough to resist drilling or fouling of the cutting surfaces of the drilling bit or milling bit. The buttons will at times tear, rupture, or otherwise alter the slip segments, and thereby become loosened from the slip segments. When the buttons become loose, the slip segments may lose some gripping capability, and are therefore susceptible to movement in the well due to the high pressures experienced in the well.

[0006] While current slip elements work well in many circumstances, there is a continuing need to increase the holding capability of the slips.

SUMMARY

[0007] A downhole tool has a mandrel and an expandable packer element disposed thereabout for sealingly engaging a well. Slip assemblies are positioned on the mandrel above and below the packer element to anchor the downhole tool in the well. Each slip assembly comprises a slip ring movable from an unset position to a set position in which the slip ring engages the well. The slip ring comprises a plurality of slip segments. Each slip segment is retained about the mandrel and is movable radially outwardly so that it will
engage the well and anchor the well tool in the well. The slip segments comprise a slip segment body with a friction medium applied to the outer surface. A plurality of inserts, or buttons may be secured to the slip segments, and will extend outwardly from the outer surface thereof. The friction medium increases the ability of the slip segment to hold the well tool in the well and to withstand pressures experienced in the well. The surface of the slip segment with the friction medium thereon may be a sandpaper-like surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a cross section of a downhole tool disposed in a well.

[0009] FIG. 2 is an enlarged cross-sectional side view of a slip segment with a friction medium applied to the outer or engagement surface thereof.

[0010] FIG. 3 is an exploded end view of two slip segments with friction medium applied to the outer or engagement surface thereof.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

[0011] Referring to the drawings, FIG. 1 shows well 10 comprising a wellbore 12 with a casing 14 cemented therein. Downhole tool 16 comprises a mandrel 18 with an outer surface 20 and an inner surface 22. The tool in FIG. 1 may generally be referred to as a bridge plug since downhole tool 16 has an optional plug 24 pinned within mandrel 18 by radially oriented pins 26. Plug 24 has a seal 28 located between plug 24 and mandrel 18. The overall tool structure would be suited for use as and referred to as a packer if plug 24 was not incorporated and fluid communication was allowed through the tool. Other components may be connected so that the packer, without plug 24 may be used, for example, as a frac plug.
A spacer ring 30 is mounted to mandrel 18 with a pin 32. A slip assembly 34 is disposed about mandrel 18 and spacer ring 30 provides an abutment which serves to axially retain slip assembly 34. Downhole tool 16 has two slip assemblies 34, namely a first slip assembly and second slip assembly which are shown in the drawings and are designated in the drawings as first and second slip assemblies 34a and 34b for ease of reference. The slip assemblies will anchor downhole tool 16 in well 10. The structure of slip assemblies 34a and 34b is identical, and only the orientation and position on downhole tool 16 are different. Each slip assembly 34 includes a slip ring 36 and slip wedge 38 which is pinned into place with pins 40.

Slip ring 36 is an expandable slip ring 36 which has a band 42 disposed in grooves 44. Retaining band 42 will retain slip ring 36 in an unset position about mandrel 18 when downhole tool 16 is lowered into the well. Slip rings 36 may be moved or radially expanded from the unset to the set position which is seen in FIG. 1 in which the first and second slip rings 36 engage casing 14 to hold downhole tool 16 in the well.

Slip rings 36 are comprised of a drillable material, for example a molded phenolic. A friction medium 37, such as for example aluminum oxide, is applied to the outer surface of the phenolic material, so that the outer surface 46 of slip ring 36 comprises the friction medium. Slip rings 36 may be made from other drillable materials as well such as drillable metals, composites and engineering grade plastics. The remainder of the slip assembly and other components of the tool may likewise be made from drillable materials. A plurality of inserts or buttons 48 are secured to slip ring 36 by adhesive or by other means and extend radially outwardly from outer surface 46. The buttons are comprised of material of sufficient hardness to partially penetrate or bite into the well casing and may be comprised, for
example, of tungsten carbide or other materials. The buttons may be, for example, like those described in U. S. Patent 5,984,007. In the set position as shown in FIG. 1, buttons 48 will engage or grip casing 14 to hold tool 16 in place.

[00015] Each slip ring 36 is preferably comprised of a plurality of slip segments 50. Slip segments 50 have inner surface 52, outer surface 54 and first and second sides 56 and 58, respectively. Outer surface 54 of each slip segment comprises a portion of outer surface 46 of slip ring 36. Slip segments 50 are shown in FIGS. 2 and 3. Slip rings 36 may include, for example, six to eight slip segments 50 that encircle mandrel 18. Slip ring 36 may include more or less than six or eight segments, and the examples herein are non-limiting.

[00016] Slip segments 50 include a slip segment body 60 which has friction medium 37 applied to the outer surface 62 thereof so that the outer surface 54 of each slip segment comprises friction medium 37. When outer surface 54 engages casing 14, friction medium 37 will engage casing 14 to increase the holding capability of slip segment 50 over the holding capability of a bare slip segment (i.e., a slip segment with no friction medium applied to the slip segment body). At least one and preferably all of slip segment bodies 60 are comprised of a drillable material, for example, a molded phenolic. The friction medium may be applied to one or more of the slip segment bodies 60 to increase the coefficient of friction between the slip segments 50 and casing 14. Friction medium 37 may be for example crushed ceramics, carbide particles, steel particles, granite particles and, as set forth above, aluminum oxide in the described embodiment. The aluminum oxide may be applied to slip segment body 60 for example by molding aluminum oxide into the phenolic slip segment body. Slip segments 50 will preferably have a sandpaper-like outer surface 54.
A packer element assembly 64 which includes at least one expandable packer element 66 is positioned between slip wedges 38. Packer shoes 68 may provide axial support to the ends of packer element assembly 64.

In operation, downhole tool 16 is deployed in well 10 using known deployment means such as for example jointed or coiled tubing. Downhole tool 16 will be in an unset position wherein tool 16 does not engage well 10. Thus, neither slip ring 36, nor packer element assembly 64 will engage casing 14 in the unset position. In the unset position, spacer ring 30, slip ring 36a and slip wedge 38a are all in an initial position about mandrel 18 and are positioned axially upwardly and radially inwardly from the set position shown in FIG. 1. When downhole tool 16 reaches a desired location in the well, each of slip rings 36a and 36b are moved radially outwardly to the set position shown in FIG. 1, and tool 16 may be left in well 10. Downhole tool 16 separates well 10 into upper well portion 10a and lower portion 10b. The upper and lower portions 10a and 10b are isolated from one another by well tool 16 which in the embodiment shown is a bridge plug. Tool 16 will typically experience high differential pressures in well 10 which will try to move the well tool 16 in well 10 after tool 16 has been set. The gripping engagement between slip segments 50 and casing 14 will hold the well tool 16 in place. Friction medium 37 at the outer surface 54 of slip segments 50 will increase the coefficient of friction over that which is seen with the material that comprises the slip segment body, and as such increases the holding capability over a bare slip segment body.

When well tool 16 is set in well 10, buttons 48 will bite, or cut into casing 14 as slip segments 50 move radially outwardly from the unset position. Outer surface 54 of at least a portion of slip segments 50 will engage casing 14 in the set position.
It is known that buttons 48 may tear or rupture the slip segment body 60 or otherwise become loosened from slip segment body 60. When this occurs, slip segment surface 54 may contact casing 14 so that all or most of surface 54 is in contact with casing 14, and friction becomes a greater component of the holding ability of slip rings 36 in well 10. The likelihood of slippage may increase in such cases. While slip segment bodies with no friction medium applied thereto provide some gripping capability, they do not provide the holding force that is provided with the slip segments described herein.

The increased coefficient of friction between friction medium 37 at outer surface 54 and casing 14 is such that an increased holding capability is supplied by slip segment 50. Slip rings 36 comprised of slip segments 50 will hold well tool 16 in place at pressures higher than is possible with bare slip segments. For example, a tool utilizing phenolic slip segments with no friction medium applied thereto can typically withstand differential pressures less than 10,000 psi without slippage. Tests have shown that a well tool with phenolic slip segments utilizing aluminum oxide as a friction medium as described herein can withstand differential pressures of greater than 10,000 psi with no slippage.

Thus, it is seen that the apparatus and methods of the present invention readily achieve the ends and advantages mentioned as well as those inherent therein. While certain preferred embodiments of the invention have been illustrated and described for purposes of the present disclosure, numerous changes in the arrangement and construction of parts and steps may be made by those skilled in the art, which changes are encompassed within the scope and spirit of the present invention as defined by the appended claims.

What is claimed is:
1. Apparatus for anchoring a downhole tool in a well comprising:
   a plurality of slip segments disposed about a mandrel of the downhole tool and movable to a set position wherein the slip segments engage the well, at least one of the slip segments made of a drillable material with a friction medium applied to the outer surface thereof for increasing the gripping capability of the slip segment to the well.

2. The apparatus of claim 1, wherein the slip segment has a sandpaper-like outer surface.

3. The apparatus of claim 1, the at least one slip segment comprising a phenolic slip segment body, the friction medium being applied to the outer surface of the slip segment body.

4. The apparatus of claim 3, wherein the friction medium is molded to the phenolic slip segment body.

5. The apparatus of claim 3, wherein the friction medium comprises aluminum oxide.

6. The apparatus of claim 1, wherein the slip segments have at least one button secured thereto and extending outwardly from the outer surface thereof for gripping the casing.

7. The apparatus of claim 1, wherein the plurality of slip segments are comprised of a non-metallic material.

8. The apparatus of claim 7, wherein the plurality of slip segments are comprised of a phenolic.
9. The apparatus of claim 8, the friction medium comprising aluminum oxide applied to the outer surface of the phenolic.

10. The apparatus of claim 8, wherein all of the slip segments include the friction medium at the outer surface thereof.

11. A downhole tool for use in a well comprising:
   
   a mandrel;
   
   a slip ring movable from a set to an unset position, wherein in the set position the slip ring grippingly engages the well, the slip ring comprising a drillable material with a friction medium applied on the outer surface thereof for increasing the gripping capability of the slip ring to the well.

12. The downhole tool of claim 11 wherein the slip ring comprises a plurality of slip segments, at least a portion of the slip segments having the friction medium on an outer surface thereof.

13. The downhole tool of claim 12, wherein the friction medium comprises aluminum oxide.

14. The downhole tool of claim 12, wherein the slip segments are comprised of a phenolic.

15. The downhole tool of claim 11 comprising an expandable packer element disposed about the mandrel and first and second slip rings, one of the slip rings positioned above the packer element and the other positioned below the packer element.
16. The downhole tool of claim 15, wherein the first and second slip rings comprise a plurality of slip segments grippingly engageable with the well.

17. The downhole tool of claim 16, wherein at least a portion of the slip segments comprises inserts extending outwardly from an outer surface thereof.

18. The downhole tool of claim 17 wherein the slip segments comprise a phenolic slip segment body with aluminum oxide applied to an outer surface thereof.

19. A downhole tool for use in a well comprising:
   
a mandrel;
   
an expandable element disposed about the mandrel;
   
a first slip ring disposed about the mandrel movable from an unset to a set position wherein the first slip ring grippingly engages the well in the set position;
   
a second slip ring disposed about the mandrel movable from an unset to a set position wherein the second slip ring grippingly engages the well in the set position, wherein at least one of the first and second slip rings has a friction medium on the outer surface thereof so that the gripping ability of the slip ring is greater than the gripping ability of a bare slip ring.

20. The downhole tool of claim 19, the first and second slip rings comprising a plurality of slip segments retained on the mandrel and movable to the set position wherein an outer surface of at least a portion of the slip segments engages the well in the set position.

21. The downhole tool of claim 20, wherein at least a portion of the slip segments comprises a phenolic slip segment body with the friction medium applied thereto.
22. The downhole tool of claim 21, the friction medium comprising aluminum oxide.

23. The downhole tool of claim 19, the slip rings comprising a phenolic having the friction medium applied to the outer surface thereof.

24. The downhole tool of claim 19, the friction medium comprising aluminum oxide.