Feb. 24, 1970 W. O. BERRYMAN ET AL 3,497,003

FRANGIBLE SOLID SLIPS WITH RETAINING BAND

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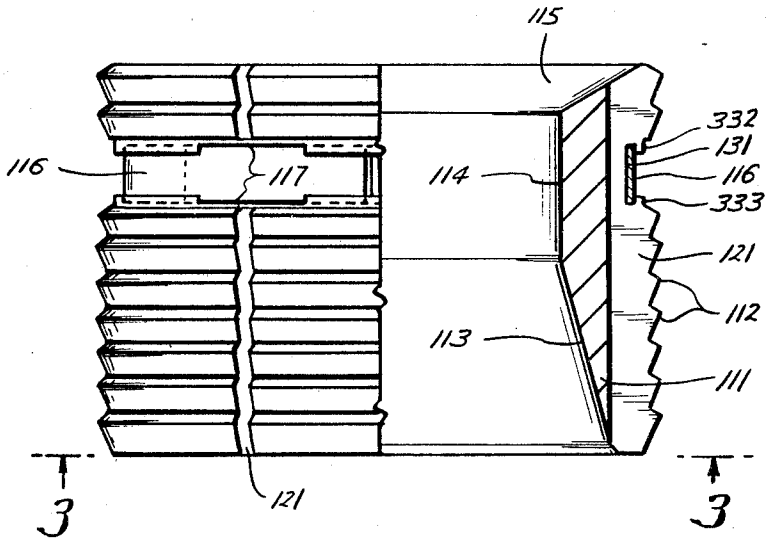

Fig. 2

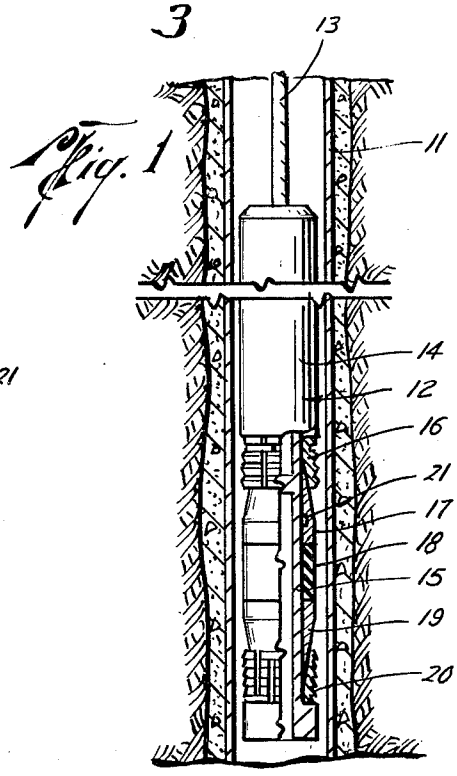

Fig. 1

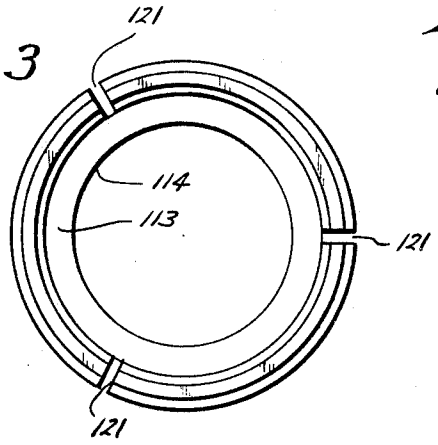

Fig. 3

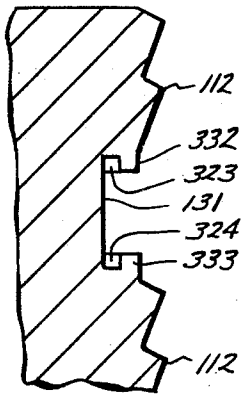

Fig. 4

William O. Berryman
James W. Kisling, III
INVENTORS

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FRANGIBLE SOLID SLIPS WITH RETAINING BAND

William O. Berryman and James W. Kisling III, Houston, Tex., assignors to Schlumberger Technology Corporation, New York, N.Y., a corporation of Texas

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U.S. Cl. 166—134 14 Claims

ABSTRACT OF THE DISCLOSURE

Disclosed is a well tool having at least one breakable slip member for use in anchoring in well bores. The slip member utilizes a plurality of longitudinal weakened sections, and, when broken into separate longitudinal segments, the segments are held in horizontal alignment during and after expansion by a force-compensating, one-way expansible retaining band. This band is keyed to a retaining slot extending around the outer circumference of the slip member.

BACKGROUND OF THE INVENTION

This invention relates to a well tool, and more particularly, to anchoring means on a well tool. Packers or plugs which are generally permanently set in a well bore typically use slip type anchoring means. The slips are generally provided with wickers or teeth on their external surface which, when the slips are expanded, bite or dig into casing or tubing wall to couple or anchor the well tool in a well bore. If it is later desired to remove the tool, this can be accomplished by drilling, milling or chipping. In these cases, it is desirable to fabricate the slips as well as the well tool from a material such as cast iron or magnesium alloys so that it may easily be broken up by the action of a bit.

The slip assembly normally must be maintained in a retracted position during passage through a well bore until such time as it is desired to anchor the tool by setting of the slips. At this time, the tool is actuated and the slips are forced radially outwardly to engage the surrounding casing and provide an anchor for the tool.

With respect to the action of the slip, it must be readily movable when desired but must not be so easily movable that it can inadvertently be actuated during passage through the well bore. One prior art approach has been to use shear screws or pins to releasably retain separate slip members relative to the tool body until a setting point is reached. Upon activation of the tool, the pins are sheared to allow the slips to be extended into gripping contact with the casing.

Another approach taken by the prior art has been a one-piece, annular slip construction using a frangible material such as cast iron. To set the slips, a conical or frusto-conical expander is forced inside the slip member to break the frangible material and form fragmented slip segments. To enhance and control the breaking action, the slip construction can have weakened sections along longitudinal planes. A one-piece slip obviously eliminates the need for shear pins to prevent accidental setting.

In a permanent type packer or the like using upper and lower, breakable, one-piece slips, if the pressure above the tool is greater than that from below, the lower slips can bite more deeply in anchoring the tool. When this occurs, the radially expanding force on the upper slips can be decreased to a point where the upper slips may tend to lose their grip on the casing and can have motion relative to the casing. To eliminate motion, radially outwardly biased spring members are sometimes used to hold the slips in contact with the casing wall.

A problem can arise in the use of either solid or shearable sectioned slips as upper slips because there is no practical way to insure that all the shear pins in the case of segmented slips, or all the weakened sections in the case of solid slips, will shear or fracture at subsantially the same time. This is true even in the case of prior art solid slips which used longitudinal weakened sections of differing strengths to promote breaking into longitudinal sections in a more controlled manner. As a result of the weakened sections not fracturing simultaneously or the pins not shearing simultaneously, one or more longitudinal slip sections from the previously unitary slip structure can prematurely fall or slide vertically along the expander cone thus horizontally misaligning the sections. Corresponding portions of the various segments do not then lie in the same horizontal plane. Misalignment of this type can prevent the maximum efficiency of the holding power of the slips from being achieved since one segment can wedge between the casing wall and the expander cone before the others and thereby receive the brunt of the load to be carried by the slip.

Prior art segmented slips have utilized snugly fitting and loosely fitting horizontally aligned guide pins joining the slip segments to maintain some mechanical linkage between the sections after the shear pins let go and thereby maintain horizontal alignment of the sections. Prior art breakable slips have been equipped with powerful radial expander springs. These springs are designed to thrust and propel the broken sections radially into immediate contact with the casing walls as soon as the slip is broken. Various radial guiding means have also been utilized in the prior art frangible slips. The present invention does not use complicated spring arrangements or radial guides to maintain the horizontal alignment of the broken sections, but rather makes use of a more simple frictional band arrangement to accomplish this end.

Accordingly, it is an object of this invention to provide a well tool with anchoring means including a one-piece fangible slip and effective economical means for maintaining horizontal alignment of corresponding segments of the slip, when broken.

SUMMARY OF THE INVENTION

In the well tool of the present invention, the anchor means includes a unitary, hollow cylinder slip member of frangible material such as cast iron. The outer surface of this member is provided with a plurality of circumferential teeth or wickers for engaging the well casing in a gripping manner upon fracture and expansion of the slip member by an expander cone. The inner surface of the slip embodying the present invention is conically tapered over a portion of its length to cooperatively engage an expander cone which is slidably mounted on the well tool's central body, in order to fracture and expand the slip. The remainder of the inner surface of the one-piece frangible slip member is of a uniform circular diameter such as to provide a sliding fit with the central body of the well tool.

A plurality of longitudinal weakened sections are defiined in the slip member by a plurality of external longitudinal notches cut at uniform intervals about the circumference of the member. The notches do not extend completely through the cylindrical walls. Near the upper shoulder of the slip member, a circumferential, lipped retaining groove is provided in the member. This groove carries and retains a unitary expansible steel band which, when the expander cone acts on the slip to fracture it into separate sections, maintains the horizontal alignment of corresponding portions of the broken sections.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation together with further objects and advantages thereof, may best be understood by way of illustration and an example of an embodiment when taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1, is a schematic partially-sectioned view illustrating the present invention utilized as an upper slip on a wireline set tool in a well bore.

FIGURE 2 is a perspective partially-sectioned view of one embodiment of the present invention illustrating its general construction.

FIGURE 3 is a bottom view of the same embodiment of the present invention illustrating the weakened sections defined by a plurality of longitudinal notches in the cylindrical walls.

FIGURE 4 is a partial longitudinal section view illustrating the circumferential retaining groove.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention concerns an improved unitary breakable slip for use on oil well tools by which the slip attains improved gripping with the walls of the well casing by utilizing novel means to assure proper horizontal alignment of corresponding portions of the broken slip segments.

In FIGURE 1, a well casing **11** is shown traversing earth formations and cemented in place. A well tool **12**, such as a permanent bridge plug, is suspended in the casing **11** by means of a wireline **13**. Wireline **13** is coupled to a standard setting tool **14** which is releasably coupled to the bridge plug **12**.

Bridge plug **12** has a central mandrel **15** which carries, from top to bottom, an upper slip **16**, an upper expander **17**, a packing element **18**, a lower expander **19**, and a lower slip **20**. The arrangement is such that when the mandrel is moved upwardly while the upper slips **16** are moved downwardly by the setting tool, the lower expander **19** moves slips **20** to anchor to the casing **11**, the element **18** is expanded and the upper slips **16** are moved by upper expander **17** to anchor to the casing. A one-way body lock **21** connects the mandrel and upper expander **17** to one another to prevent the mandrel from moving downwardly relative to expander **17**.

Lower slips **20** have alternate, longitudinally extending grooves from respective end surfaces to provide an integral annular member which can be radially expanded without fracture of the member. Further details on the lower slip **20** can be found by reference to U.S. Patent No. 3,298,440.

Referring now to FIGURE 2, it is seen that the upper slips comprise a one-piece integrally formed, cylindrically shaped slip member **111** made of a frangible material, preferably cast iron. The outer surface of member **111** is provided with a plurality of circumferential teeth or wickers **112** for grippingly engaging the inner surface of the well casing. A portion **113** of the cylindrically shaped inner surface of the member is longitudinally tapered to cooperate with the outer surface of an expander cone in a well-known manner. The remaining portion **114** of the inner surface is of uniform diameter and sized to a sliding fit on the body of a well tool.

The upwardly facing shoulder **115** on the slip member **111** is tapered as shown in FIGURE 2 for cooperative engagement with a setting sleeve on the setting tool or well tool. A circumferentially extended recess **131** of uniform diameter is provided in the member near its upper shoulder **115** and is adapted to receive a unitary expansible steel band **116**. Recess **131**, as shown in larger detail in FIGURE 4, has upper and lower annular grooves **323** and **324** formed by upper and lower flanges **332** and **333**. At one point around the circumference, there is a circumferential gap **117** in the flanges which is sized so as to permit expansible band **116** to be inserted into recess **131**. Band **116** is greater in length than the circumference of the recess and the width of the grooves **323** and **324** is greater than the thickness of the band so that the band can be slid around the circumference of the recess **131** until the band completely encircles member **111** and overlaps itself. The width of the band is made sufficient so that the band is contained within the grooves **323** and **324** of the member **111**.

Band **116** is made of a material such as cold-rolled steel which is sufficiently flexible to permit flexing as the member **111** is expanded. During expansion, an expander acts on the conically tapered lower portion **113** of slip member **111** thereby breaking the slip member **111** along the longitudinal weakened sections defined by exterior longitudinal notches **121**. The action of band **116** after breaking has taken place is to exert sufficient retaining force to prevent one broken section of member **111** from moving longitudinally relative to the remaining part or parts of member **111**. Thus, the member **111** is maintained in horizontal alignent while being fragmented. Band **116**, however, because of friction and composition is a force-compensating expansible band and, as such, does not exert an outward radial spring force relative to any broken sections of member **111**. Any substantial radial spring action present in band **116** is counteracted by the forces of sliding friction of band **116** in recess **131** and grooves **323** and **324**. Thus, there is no effective net radial spring force applied to the broken section by band **116**.

After fracturing has occurred along the weakened sections defined by notches **121**, band **116** serves to maintain horizontal alignment of the broken sections of member **111** as the broken sections are expanded radially outward by the expander cone **12**. During this movement, of course, the diameter of the assembly formed by the broken sections and linked by band **116** is steadily increasing and the overlapping portion of band **116** in recess **131** gets progressively shorter.

Since horizontal alignment of teeth **112** of the fractured sections is maintained throughout the expansion of the broken sections by band **116**, the teeth **112** effectively engage the wall of the casing uniformly (i.e., along the circumference of a circle rather than along an elliptical arc, or an erratically shaped path) and are thus enabled to bite evenly into the wall of the casing. This provides a more uniform load distributed grip by teeth **112** than would otherwise be afforded. The overall length of band **116** is desirably at least equal to the circumference of the well casing to maintain the interconnection of the slip segments when they are in a fully expanded condition.

If a pressure differential exists across well tool **42** such that the pressure is greater from above, then lower slips **20** will carry most of the load. In a case such as this, the present invention will not lose its grip on well casing **11** even if relieved of radial expansive pressure. The frictional engagement of force-compensating, expansible band **116** with the flanges **332** and **333** of recess **131** and the wall of the recess is such that the expanded slips cannot collapse in a radial direction. A uniform inward radial pressure from all sides would be necessary to cause band **116** to slide back into its ends overlapping state of origin. If net inward radial pressure is applied at only one section of the broken slip, as would generally occur if lower slip **20** carried the load, band **116**, because of its flexibility, will assume an elliptical or irregular shape and wedge portions of its length between the flanges **332** and **333** and the wall of recess **131** so forcefully that it will effectively lock all the broken sections into place. Band **116** behaves, therefore, as a one-way expansible band and prevents the loss of grip of the slips once they have set.

If desired, the one-way expansion of band **116** can further be controlled by arranging the overlapping portion with a set of one-way ratcheting teeth.

While one particular embodiment of the present invention has been shown and described, it is apparent that changes may be made without departing from this invention in its broader aspects; and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. A slip assembly for use in a well tool comprising:
an integral, annular, breakable slip member having weakened sections arranged for providing independent wall-engaging slip elements when moved between radially contracted and expanded positions; and
means for controlling the relative positional relationship of slip elements including a member encircling said slip member and means providing a frictional retaining force between said slip member and said encircling member, said encircling member having sufficient length to continuously couple slip elements to one another while moving between contracted and expanded positions and at an expanded position, said frictional retaining means serving to retain a circumferential dimensional relationship of slip elements relative to the encircling member.

2. Anchoring means for anchoring a well tool in a well bore comprising:
an annular, one-piece, breakable slip member having arcuately spaced weakened sections along its circumference adapted to break during setting of said slip member to form slip segments which can move radially to engage the wall of a well bore;
gripping means distributed about the outer surface of said slip member for gripping the wall of a well bore;
a force-compensating, one-way expansible band around an outer surface of said slip member; and
means for retaining said expansible band relative to said outer surface of said slip member, said band maintaining broken slip segments, when produced, in horizontal alignment.

3. The apparatus of claim **2** wherein said band has a length such that it overlaps its ends and provides a continuous support when the slip segments are moved radially into engagement with a well bore.

4. The apparatus of claim **2** wherein said slip member has an inner, conically tapered surface over at least a portion of its length, for cooperative engagement with an expander cone.

5. The apparatus of claim **4** wherein said weakened portions for breaking of said slip member are disposed along predetermined longitudinal directions.

6. In a breakable slip member adapted for anchoring a well tool in a well bore, the combination comprising:
means for breaking said slip member into longitudinal segments for setting;
a force-compensating, one-way expansible band disposed around an outer surface of said slip member; and
means for frictionally coupling said expansible band to said slip member, said band maintaining horizontal alignment of slip segments produced during setting of said slip member and maintaining such alignment irrespective of the radial position of any such slip segments.

7. The combination of claim **6** wherein said coupling means comprises a circumferential flanged recess in the outer surface of said slip member.

8. Means for anchoring a well tool in a well bore, comprising:
a body member, slip and expander means on said body member, said slip means having inner tapered surfaces engageable with outer tapered surfaces on said expander means to enable outward shifting of said slip means by said expander means;
circumferentially extending groove means in said slip means; and
band means trapped in said groove means, said groove and band means sized to cooperate in a manner whereby outward pressure must be exerted by said expander means on said slip means to effect outward shifting of said slip means, said band and groove means also functioning to hold corresponding portions of said slip means in a common horizontal plane.

9. The combination of claim **8** wherein said groove means extends around the outer periphery of said slip means.

10. The combination of claim **8** wherein said groove means has oppositely facing wall surfaces frictionally engaging complementary wall surfaces of said band means.

11. The apparatus of claim **8** wherein said band has a length such that it overlaps its ends and provides a continuous support when the slip means are shifted outwardly into engagement with a well bore.

12. Anchoring means for anchoring a well tool in a well bore comprising:
an annular, one-piece breakable slip member having circumferentially spaced longitudinal weakened sections adapted to break during setting of said slip member to form longitudinal slip segments which can move radially outward;
a plurality of circumferential teeth distributed along the outer surface of said slip member;
a force-compensating, one-way expansible band around an outer surface of said slip member;
a circumferentially extending grooved recess in the outer surface of said slip member for retaining said expansible band on said slip member, said band maintaining broken longitudinal sections of said slip member in horizontal alignment when said slip member is broken; and
an inner, conically tapered surface on said slip member extending over at least a portion of its length, to cooperatively engage with an expander cone.

13. A well tool for use in a well bore comprising:
a mandrel;
expandable packing means on said mandrel adapted to provide a seal with respect to the wall of a well bore;
means on said mandrel for anchoring said well tool in a well bore when said packing means is expanded, said anchor means including at least one breakable slip means and expander means mounted on said mandrel;
a force-compensating, one-way expansible band around an outer surface of said slip means; and
means for frictionally coupling said band to said outer surface of said slip means, whereby when said slip means is broken by said expander means, said band retains the broken sections in horizontal alignment as said broken sections are expanded radially outward.

14. A well tool for use in a well bore comprising:
a central mandrel;
expansible packing means on said mandrel adapted to provide a seal with respect to the wall of a well bore;
an expander cone slidably mounted on said mandrel; and
slip means for anchoring said tool in the well bore, said slip means including:
a one-piece, annular, breakable slip member having a plurality of weakened sections arcuately spaced about its circumference to promote breaking thereof along predetermined longitudinal directions;

a plurality of circumferential teeth distributed along the outer surface of said slip member;

a force-compensating, one-way expansible band around an outer surface of said slip member;

a circumferentially extending grooved recess in the outer surface of said slip member for retaining said expansible band on said surface, and for maintaining broken longitudinal sections of said slip member in horizontal alignment when said slip member is broken; and

an inner, conically tapered surface on said slip member extending over at least a portion of its length, to cooperatively engage said expander cone.

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DAVID H. BROWN, Primary Examiner

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