

[54] **APPARATUS FOR ROTATABLY SUSPENDING A PIPE STRING IN A WELL**

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[51] Int. Cl.**E21b 43/10**

[58] Field of Search**166/208; 308/135, 160, 164, 308/238**

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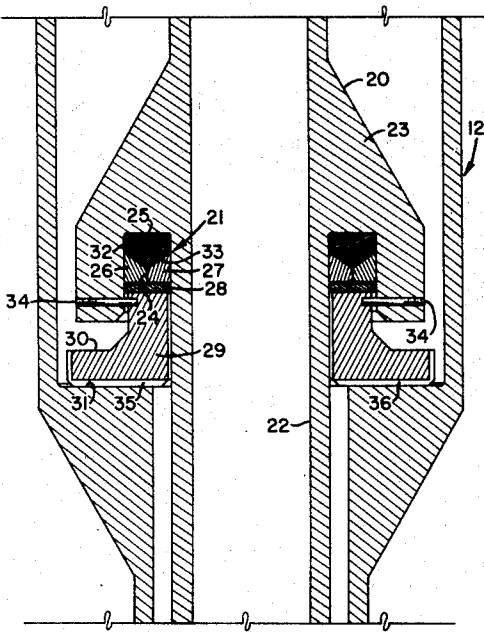
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[57] **ABSTRACT**

An apparatus for rotatably suspending a pipe string in a well includes a rotating member, a stationary member, and a bearing assembly. The bearing assembly is mounted in a chamber defined by the rotating and stationary members and is interposed between axially spaced and transversely extending bearing surfaces formed, respectively, in the stationary and rotating members. The bearing assembly includes a plastic ring positioned in the chamber to engage one of the bearing surfaces and two concentric metal rings positioned in the chamber to substantially cover the other bearing surface. The engagement of the plastic ring on the metal rings is such to force the metal rings radially apart and against opposite interior surfaces of the chamber as thrust loads are applied to the apparatus.

17 Claims, 4 Drawing Figures



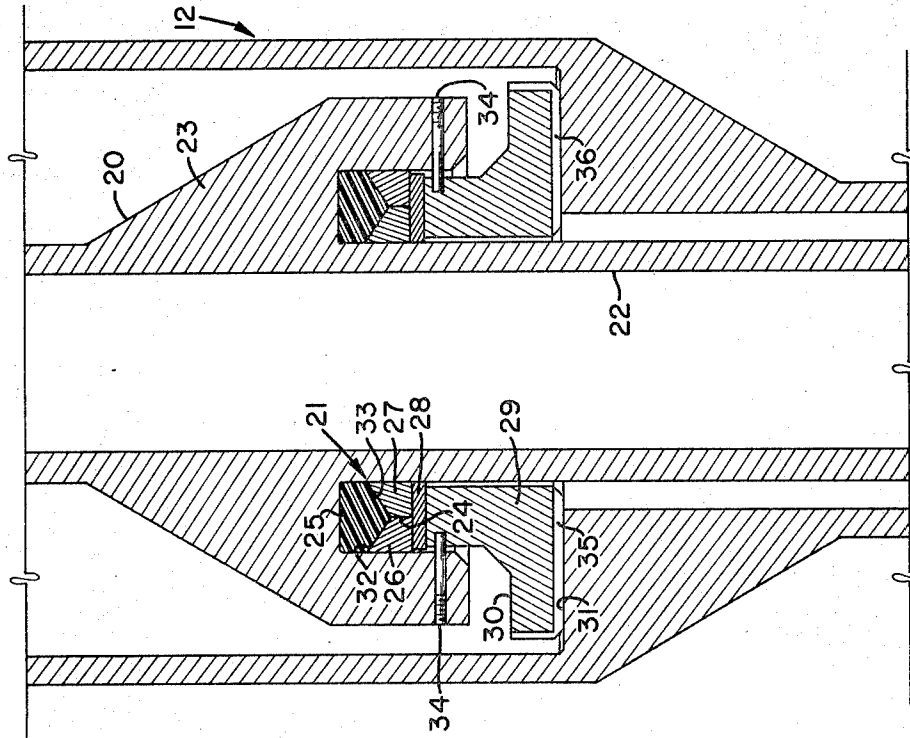


FIG. 2

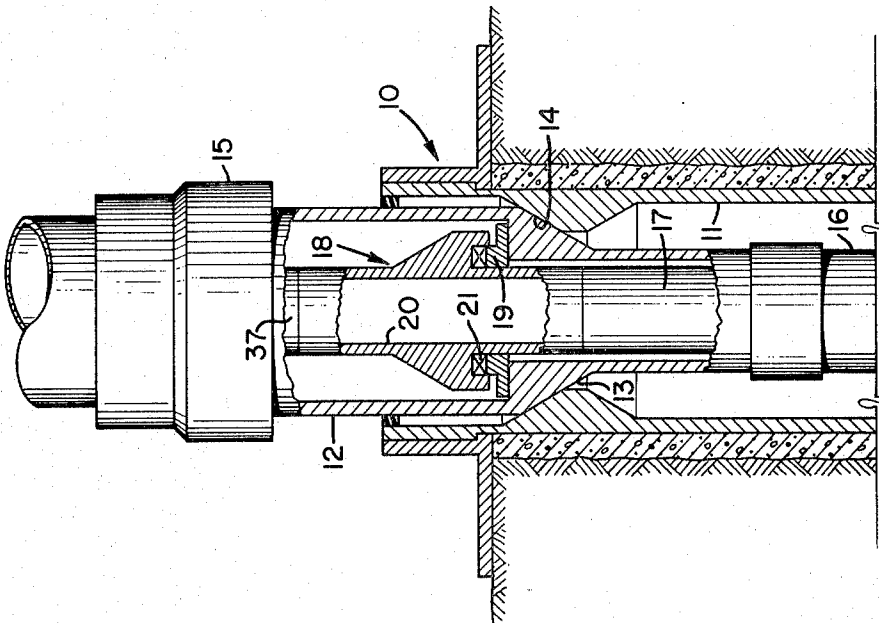


FIG. 1

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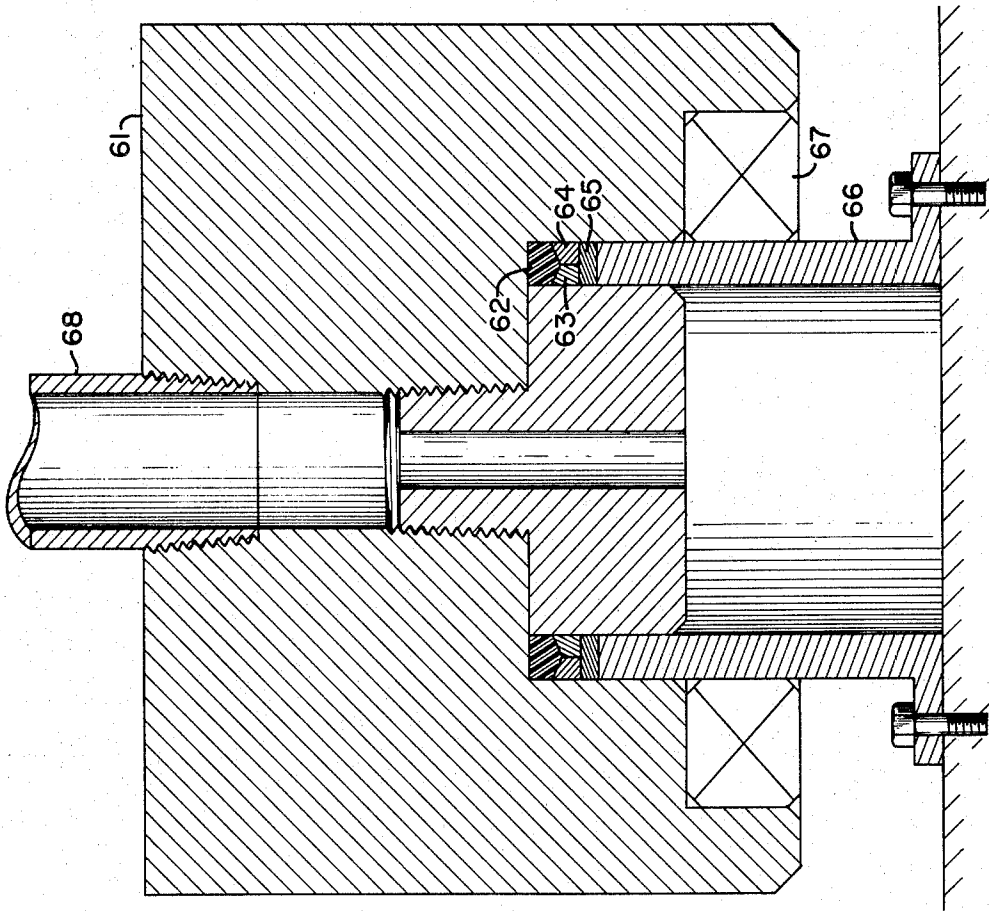


FIG. 4

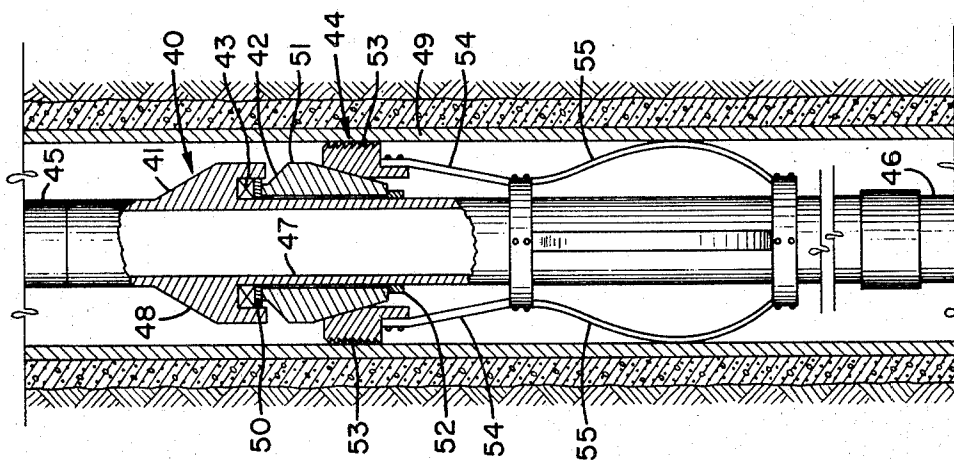


FIG. 3

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APPARATUS FOR ROTATABLY SUSPENDING A PIPE STRING IN A WELL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an improved pipe hanging apparatus usable in well completion operations.

2. Description of the Prior Art

In completing an oil well, gas well, water well, or similar borehole, it is customary to case the well with heavy steel pipe and provide a cement sheath about the outer periphery of the pipe. The cement sheath adds strength to the pipe string, protects the metal from corrosion, and prevents migration of fluids between subsurface formations. For the cement to be effective, it is essential that it substantially surrounds the pipe string. Placement of the cement about the pipe normally involves positioning the pipe string in the wellbore and pumping a cement slurry down through the pipe string and up the wellbore annulus. The cement slurry displaces the drilling mud ahead of it. Because of the relatively high gel strength of most drilling muds, complete displacement of the drilling mud by the cement slurry is difficult to achieve, particularly with long pipe strings. Experience has shown that the cement slurry tends to channel through the drilling mud, resulting in a nonuniform cement sheath about the pipe string. One approach for improving the displacement operation involves a technique wherein the pipe is rotated as the cement slurry is pumped through the pipe string and up the well bore annulus. Tests have shown that pipe rotation improves mud displacement in two important respects: it breaks the gel structure of the mud and it eliminates stagnant pockets of mud in the wellbore annulus. For wells drilled on land, rotation can be achieved by suspending the casing on the drilling swivel and applying torque to the casing by the rotary table. For offshore wells drilled with floating vessels, however, use of the swivel to suspend the pipe is not possible because of vessel motion. Vessel motion requires that the casing be suspended on the subsea wellhead assembly. The radial space for accommodating the casing hanger in most subsea assemblies is limited. This limited "bowl" space does not provide sufficient radial clearance to permit the use of rolling-element bearings having sufficient load carrying capacity to support the casing string. The cementing of such pipe strings is thus generally performed without the known benefits of pipe rotation. As previously noted, this substantially increases the risk of obtaining a poor cement job.

Another application where pipe rotation is desirable is in liner installations. A liner is a pipe string suspended within an existing casing string in the wellbore. It is normally employed where it is not necessary for the inner pipe to extend to the surface. Considerable savings in pipe cost can be realized by suspending the liner within a lower portion of the outer casing string. Rotating liner hangers are commercially available and normally include a ball bearing for carrying thrust loads. Such assemblies, because of their limited load carrying capacity, are normally used to set relatively short lengths of liners. This somewhat limits the utility of rotating liner hangers because, as previously noted, the mud displacement problem is particularly serious in long pipe strings.

SUMMARY OF THE INVENTION

The improved apparatus constructed according to the present invention can be used in connection with casing hangers, liner hangers, or other applications where it is desired to rotatably support a pipe string in a well. Briefly, the apparatus includes a stationary member, a rotatable member, and a bearing assembly for carrying thrust loads. As applied in connection with pipe hanging assemblies, the stationary member is designed to be secured to the wellhead assembly or outer casing, and the rotatable member is designed to carry the pipe string to be cemented in the borehole. When assembled, the stationary member and rotatable member define a substantially enclosed chamber which contains the thrust bearing assembly. The thrust bearing assembly comprises two rings composed of relatively soft bearing metal such as copper or bronze alloys and a plastic ring having a relatively low coefficient of friction. The bearing assembly is positioned within the chamber in such a manner that the plastic ring engages one of the members, e.g., rotating member, and the two metal rings arranged in concentric relation substantially cover the gap between the two members to prevent excessive extrusion of the plastic ring. The metal rings preferably are sized in relation to each other to provide a relatively small clearance therebetween. The plastic ring engages both metal rings and is shaped in relation to the confronting surfaces of the metal rings to provide a radial component of force on each metal ring as load is applied to the assembly. Applied load, thus, tends to force the metal rings apart into sealing engagement with the chamber walls.

The surface of the member engaging the metal rings preferably is faced with a hard, wear-resistant material such as one of the nickel-chromium-boron alloys.

The thrust bearing assembly requires substantially less radial mounting space than that required for rolling-element bearings of comparable load carrying capacity. Pipe hangers provided with the bearings assembly can be readily suspended in subsea assemblies as well as within casing strings and permit rotation of substantially longer pipe strings therein than previously possible. Tests have shown that the apparatus of the present invention can support thrust pressures as high as 10,900 psi for several hours with no noticeable deterioration of the bearings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic view, shown partially in longitudinal section, of a portion of a subsea well assembly illustrating the apparatus in connection with casing hangers.

FIG. 2 is an enlarged, fragmentary view of the apparatus shown in FIG. 1 showing details of the improved apparatus.

FIG. 3 is a longitudinal sectional view of a portion of a cased wellbore illustrating the apparatus in connection with a liner hanger.

FIG. 4 is an elevational view, shown in longitudinal section, of a test rig employing the support apparatus of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

For purposes of illustration, the present invention will be described in connection with a casing hanger and a liner hanger. It should be emphasized, however, that the improved apparatus can be used in other applications where it is desired to rotatably suspend a pipe string in a well.

Depending upon pipe diameter, pipe location, and pipe use, pipe strings are referred to in the art as drilled pipe, casing, tubing, or liners. As used herein, the terms "pipe" or "pipe string" embrace the wide variety of conduits commonly used in the drilling, completion, and repair of wells.

Considering first the embodiment in connection with casing hangers, FIG. 1 schematically illustrates a subsea wellhead assembly for a floating drilling vessel. The assembly comprises a guide structure 10 resting on the ocean floor, a surface pipe string 11, and a hanger mandrel 12. The surface pipe string 11 is suspended on the guide structure 10 and is cemented in place. The hanger mandrel 12 has a cone section 13 which mates with an internal shoulder, or "bowl," 14 secured to the surface pipe 11. The mandrel 12 serves several functions: it provides means for supporting components of the subsea assembly which include a hydraulic connector, illustrated as 15, blowout preventors, marine conductor pipe, and similar equipment; it also provides a support base for suspending pipe strings installed during the drilling of the well. In deep wells, the mandrel 12 will normally provide support for several casing strings. For example, one common design calls for 30 inch diameter surface pipe, three intermediate casing strings of 20 inch diameter, 13 $\frac{1}{2}$ inch diameter, and 9 $\frac{1}{2}$ inch diameter, and a production string of 7 inches in diameter. Thus, it is seen that FIG. 1 is somewhat simplified in that only the surface pipe string 11, intermediate pipe string 16, and a production string 17 are shown. Cementing of the intermediate pipe strings which are relatively short in relation to the production string 17, normally is not difficult to achieve because the relatively large annulus between the casing and the borehole favors mud displacement by the cement slurry. The production string 17, on the other hand, is extremely difficult to cement because of the mud displacement problems described earlier. Factors which promote cement channeling through the mud include small clearance between the casing and borehole, relatively long lengths of pipe, and the eccentric location of the pipe string in the borehole. These factors coupled with the gel characteristics of the mud make it extremely difficult to obtain a competent cement sheath about the production string. It has long been known that pipe rotation during cementing operation improves the displacement mechanism. The rotating pipe breaks the gel structure of the mud and eliminates stagnant pockets in the annulus. As mentioned earlier, rotation of long pipe strings suspended from floating vessels has not been possible, heretofore, because of vessel motion. Moreover, the limited bowl space in subsea wellhead assemblies precludes the use of conventional bearings. As illustrated in FIG. 1, the casing hanger must be sufficiently small to pass through the upper components of the subsea assembly and to lodge in the mandrel 12.

A feature of the apparatus of the present invention is that it requires relatively small radial mounting space and therefore can readily be mounted in the mandrel 12.

The apparatus shown generally as 18, includes a stationary member 19, a rotating member 20, and a bearing assembly 21. The rotating member 20 is adapted to carry the pipe string 17 whereas the stationary member 19 is adapted to seat in the mandrel bowl. The bearing assembly 21 permits relative rotation of the members 18 and 19 as torque is applied to the running-in string at the surface.

Referring to FIG. 2, the rotating member 20 is seen to include a tubular body portion 22 and a flanged portion 23 which extends radially outwardly from body portion 22. The axial opening through the apparatus should have a diameter about the same as the casing string 17 suspended therebelow. Formed in the flanged portion 23 is a downwardly opening annular groove sized to receive bearing 21 and associated components. The bearing 21 comprises a three ring assembly including a plastic ring 25 and two metal rings 26 and 27. The plastic ring 25 fits into the upper portion of the groove and engages a downwardly facing bearing surface of member 20. The two rings 26 and 27 arranged concentrically in the groove define an upper surface shaped complementary to the lower surface of plastic ring 25. The stationary member in this embodiment comprises two parts, washer 28 and retainer 29. The washer 28 is sized to fit into the groove and therein provides an upwardly facing bearing surface. The three ring bearing assembly 21 and washer 28 are maintained within the groove by the retainer 29. In a sense then the washer 28 and rotating member 20 cooperate to define a substantially enclosed chamber having confronting axially spaced and transversely disposed bearing surfaces. The plastic ring 25 is adapted to bear against one of the bearing surfaces and the concentric rings 26 and 27 against the other. The retainer 29 bears against the bottom surface of the washer 28 and has a lower flanged portion 30 adapted to seat in the "bowl" or mating surface 31 formed in the mandrel 12. Several radial flow channels, two shown as 35 and 36, formed in the bottom surface of flange 30 permit drilling mud to flow around the apparatus during cementing operations.

The rings 26 and 27 are arranged in side-by-side, concentric relation in the groove and each has a downwardly facing surface engaging the top surface of the washer 28 and a radially facing surface confronting a wall of the groove. The inner surface of ring 26 confronts an outer surface of ring 27 along an interface (shown as line 24 in FIG. 2). The clearance between the rings 26 and 27 along interface 24 should be sufficient to permit relative rotational movement of the rings 26 and 27. This clearance can vary within relatively wide limits depending on the size of the rings 26 and 27, pressure imposed on the apparatus, and materials employed. Preferably, the clearance should be such to provide a sliding fit between the rings 26 and 27, e.g., clearance less than 5 mils; preferably between 0 and 2 mils.

Upper surfaces 32 and 33 of rings 26 and 27, respectively, can be tapered as illustrated. These surfaces mate with the lower complementary shaped surface of plastic ring 25. As thrust loads are applied to the as-

sembly, the mating relationship of ring 25 on surfaces 32 and 33 results in a radial component of force on each of the bearing rings 26 and 27. The outer ring 26 is forced into abutting engagement with the outer confining surface of the groove and the inner ring is forced into abutting engagement with the inner surface of the groove. The rings 26 and 27 thus substantially cover the radial spaces between the washer 28 and the walls of the groove and prevent excessive extrusion of the plastic ring 25. It should be observed that the specific configurations of the rings 25, 26, and 27 can be other than that disclosed. These configurations, however, must be such to force the concentric rings apart in response to axial thrust loads on the apparatus 18.

The bearing rings 26 and 27 can be made of any metal bearing material. Preferably, the bearing material is of intermediate compressive strength. The hardness and modulus of elasticity of these materials should generally be as low as possible and yet provide sufficient strength to carry the applied load. Preferred bearing materials include bronze, leaded bronze, tin bronze, phosphor bronze, as well as copper-lead alloys and similar bearing materials. These materials are relatively soft having a Brinnell hardness less than 100 and a relatively low modulus of elasticity.

The bearing rings 26 and 27 can be machined to the proper dimensions by conventional techniques. The size of the rings 26 and 27 should be such that they can be assembled in concentric relation and inserted into the groove. The clearance between each ring and the wall of the groove normally will be between about 2 and 6 mils to permit easy installation.

The plastic ring 25 occupies substantially all of the space of the groove above the bearing rings 26 and 27. The plastic ring can be molded from most any dry bearing plastic, the most popular of which includes nylon polycarbonates, acetals and the fluoroplastics. The fluoroplastics, particularly polytetrafluoroethylene, are preferred because of their low coefficient of friction, high temperature resistance, and good lubricating qualities. These plastic materials can be molded into the desired configuration by known molding techniques. As indicated above, the top and outer surfaces of the plastic ring 25 are shaped complementary to the confining walls of the groove and the bottom surface is shaped complementary to the top surface defined by the assembled rings 26 and 27.

As mentioned previously, the washer 28 should be faced with a hard, wear-resistant surface. A steel core faced with nickel-chromium-boron alloy has proven satisfactory for this service. The alloy sold under the trade name Colmonoy provides a highly polished, hard, wear-resistant surface. Other hard facing materials include high chromium iron, cobalt chromium alloy, and copper base alloys. The nickel-chromium-boron alloys are preferred, however, because they are highly wear-resistant, and retain their hardness at elevated temperatures.

The installation of the apparatus 18 when applied in connection with casing hangers can be performed as follows. When the well has been drilled to the proper depth, the drill string is withdrawn from the wellbore and a casing string denoted 17 in FIG. 1 is lowered into the hold by conventional techniques. The apparatus 18 comprising rotatable member 20, bearing assembly 21,

and the stationary member (washer 28 and retainer 29) is secured to the top joint of the casing string 17. The retainer 29 may be held in place by mechanical means such as a plurality of shear pins, two shown as 34 in FIG. 2, extending radially through the flange 23 and having inner end portions protruding into suitable recesses formed in retainer 29. The apparatus 18 connected to the casing string 17 is lowered to the proper setting location on a pipe string 37 of the same diameter as casing 17. This assembly is run into the hole until the retainer flange 30 seats on the mandrel bowl surface 31. This transfers the weight of the casing 17 to the mandrel 12. Initial torque applied to the string 37 at the surface causes the pins 34 to shear, permitting rotation of member 20 on the stationary portion of the apparatus. The thrust loads applied on the bearing assembly cause the plastic ring 25 to deform and substantially conform to the shape of the upper extremity of the chamber. The plastic material thus acts much in the manner of the viscous fluid applying a hydraulic force on the bearing rings 26 and 27 forcing them apart into engagement with their respective chamber walls. Engagement of the bearing rings 26 and 27 on the chamber walls prevents excessive axial extrusion of the plastic material between the rings 26 and 27 and the walls of the groove.

Although it is not clear which of the rings 25, 26 and 27 remain stationary and which rotate, the wear pattern on test assemblies indicate that part of the time the outer ring 26 remains stationary and that the plastic ring 25 and inner ring 27 rotate. The plastic material tends to extrude at a slow rate between the rings 26 and 27 and the groove walls and along interface 24 providing lubrication for the sliding surfaces. The extruding plastic also provides lubrication for the sliding surfaces between washer 28 and ring 26 and/or ring 27.

During pipe rotation, cement can be pumped through the running-in pipe string 37, the casing 17 and up the wellbore annulus displacing drilling mud ahead of it. The drilling mud flows through the channels 35 and 36 in the retainer flange 30 and to the surface. After the cement has been placed, the running-in pipe string 37 can be disconnected from the rotating member 20 and retrieved. In some applications it may be necessary to run a packer to seal the annulus above the flange 23 to close off the flow channels 35 and 36.

Another embodiment of the invention is disclosed in connection with a liner hanger, shown in FIG. 3. A liner is generally installed in lieu of a complete casing string in order to save on material cost. Liners are normally suspended in a lower portion of an existing casing and cemented in place. A liner hanger attached to the top of the liner is required in order to secure the assembly to the existing casing. Although rotating liner hangers have been used in the past, their limited load carrying capacity has restricted their use to relatively short liners. The apparatus of the present invention permits the suspension of relatively long liners.

The liner hanger 40 comprises a rotating head 41, a stationary member 42, a bearing assembly shown generally as 43, and a slip assembly 44. The upper end of the head 41 is adapted to be connected to a running-in string 45, e.g., tubing, drill pipe, etc., and the lower end is adapted to be connected to a liner 46. The running-in string 45 may also include a setting tool (not

shown) which functions to collapse packers after the cementing operation is completed.

The rotating head 41 includes a tubular body portion 47 and a flange 48 which extends radially outwardly from the body 47. The inside diameter of the head 41 is preferably the same as that of the liner 46. The flange 47 has formed therein an annular, downwardly opening groove sized to receive the three ring bearing assembly 43, which is generally the same construction as previously described, having a plastic ring and two metal rings. Because of the space limitations between the liner 46 and existing casing shown as 49, the bearing assembly 43 used in liner hangers probably will be somewhat smaller in radial dimension than the bearing assembly used in casing hangers described previously.

The bearing assembly 43 bears against a washer 50 which closes the groove opening. The washer 50 has an upper bearing surface engaging the bottom surface of the bearing assembly 43 and preferably is faced with a hard, wear-resistant material such as a nickel-chromium-boron alloy. The washer 50 and bearing assembly 43 are maintained within the groove by top surface of a slip expander cone 51. The cone 51 extends circumferentially around the tubular portion 47 and is sized in relation thereto to permit free rotation of the two members. A stop collar 52 secured to the tubular portion 47 maintains the cone 51 in place during running-in operations. The slip assembly 44 includes a plurality of gripping jaws 53. Each gripping jaw 53 is riveted or otherwise connected to a spring member 54 which is an extension of a bow spring 55. The bow springs 55 are shaped to frictionally engage the well casing 49. During running-in operations, the gripping jaws 53 are maintained in a retracted position below the cone 51. At the proper setting depth the jaws 53 are released by reciprocation of the pipe or by hydraulic action depending upon the mechanism employed. Lowering of the pipe then causes the jaws 53 to be wedged between the casing 49 and cone 51 as illustrated in FIG. 3.

In operation, the liner 46 and hanger 40 are lowered into the cased wellbore on a running-in pipe string 45 which as previously noted can include a setting tool of conventional construction. At the proper setting depth, the slip assembly 44 is actuated, causing the slip jaws 53 to be wedged between the cone and the casing. This transfers the load of the liner 46 and running-in assembly to the stationary portion of the hanger, e.g., washer 50, cone 51, and slip jaws 53 which are, in turn, supported on the well casing 49. As cement is pumped from the surface through the running-in string 45, the hanger 40, the liner 46, and up the casing-liner annulus, the pipe string is rotated by applying torque at the surface. The drilling mud displaced by the cement flows up the annulus passing around the liner hanger 40. Following the cementing operations, the running-in string is disengaged from the liner hanger 40 and retrieved. The liner hanger 40 constructed according to the present invention, because of the increased load carrying capacity of the bearing assembly 43, is capable of supporting substantially longer liners than are commercially available liner hangers.

The following laboratory experiment illustrates the effectiveness of the apparatus of the present invention. A test assembly shown in FIG. 4 was constructed. The assembly included a steel head member 61 having a

downwardly opening groove formed therein. The groove had an outside diameter of 3.533 inches and a thickness of 0.721 inches. A bearing assembly comprising a plastic ring 62 of polytetrafluoroethylene and two bearing rings 63 and 64 of phosphor bronze (SAE 660) were placed in the groove. The polytetrafluoroethylene ring 62 was 3.529 inches in outside diameter, 0.713 inches thick, and 0.375 inches in height (from tip to base). The inside and outside diameters of the inner ring 63 were 2.816 and 3.173 inches, respectively, and the inside and outside diameters of the outer rings 64 were 3.173 and 3.529 inches, respectively. The rings 63 and 64 were 0.250 inches in height and had upper, inwardly tapering shoulders which defined an included angle of 110°. A washer 65 faced with Colmonoy hard, wear-resistant alloy was inserted in the groove. The washer 65 had inside and outside diameters of 2.817 and 3.528 inches, respectively, and a height of 0.310 inches. The head 61 and bearing assembly were placed on the upper end of a short joint of pipe 66. The pipe bolted to a base had inside and outside diameters of about 2.85 and 3.50 inches, respectively. A radial bearing 67 having an inner race secured to the pipe 66 and an outer race secured to the head 61 maintained the pipe 66 and groove in axial alignment. The head 61 was connected to a hydraulic press, a portion shown as joint 68. The test apparatus included a rotary table for rotating joint 68 and a torque transducer for measuring the applied torque. A load of 40,000 pounds was applied to the head 61 as the assembly was rotated at 20 rpm. The 40,000 load resulted in a pressure of about 10,900 psi on the thrust bearing. The initial torque required to maintain 20 rpm was about 280 foot-pounds. After 3½ hours, the test was discontinued for 10 minutes. When the test was resumed at same operating conditions, the torque required to rotate the assembly at 20 rpm with applied load of 40,000 pounds was initially about 550 foot-pounds. The torque leveled off to about 350 foot-pounds in about 2 minutes and then, after about 10 minutes, increased to about 380 foot-pounds. The test was discontinued. The test apparatus was disassembled. The plastic ring 62 and bearing rings 63 and 64 were intact and showed very little wear. The following morning, the test was resumed and continued for 3½ additional hours. During the final 25 minutes, the torque was somewhat erratic, increasing to about 700 foot-pounds at one point and 600 foot-pounds at another. At the conclusion of the test, however, the assembly was rotating smoothly at an average torque of about 430 foot-pounds. Following the test, the test apparatus was disassembled. The plastic ring 62 had split along a horizontal plane near the base of the tapered portion. The lower bearing surface of outer ring 64 was badly pitted whereas the corresponding surface of inner ring 63 showed no evidence of pitting. The outer periphery of ring 64 was worn indicating relative motion between that ring and the wall of the groove. The inner surface of ring 63 was not worn indicating that that ring was secured to the head 61. The interface between the rings 63 and 64 appeared to be a sliding surface, the height of which was about one-half of the original height of the interface. Above this sliding surface was a V-shaped groove about one thirty-second inch wide. This groove extended from the sliding surface to the top of the original interface. There was evidence of lubrica-

tion by the plastic between the outer periphery of ring 64 and the groove wall. There was also evidence of plastic lubrication between the bottom surface of ring 64 and washer 65.

The above test shows that the apparatus of the present invention has sufficient load carrying capacity to support relatively long strings of pipe for several hours. The reason for the improved results are not clearly understood. It is believed, however, that the lubrication provided by the plastic material extruding between sliding surfaces plays a major role. The radial component of force on the rings 63 and 64 forcing them apart appears to prevent excessive axial extrusion of the plastic material. This force also causes the rings 63 and 64 to conform to the walls of the groove thereby compensating for wear.

Although the improved apparatus has been described mainly in connection with casing and liner hangers, it again should be emphasized that the invention can be applied equally well in other applications where it is desired to rotatably suspend a pipe string in a well.

We claim:

1. An apparatus for rotatably suspending a pipe string in a well which comprises a stationary member adapted to be secured to a supporting structure for said well; a rotating member adapted to be connected to said pipe string, said stationary and rotating members in combination defining an annular chamber therebetween including two axially spaced and transversely disposed bearing surfaces; two concentric rings of bearing metal substantially covering one of said surfaces; and a plastic ring between said concentric rings and the other of said surfaces, the engagement of said plastic ring on each of said concentric rings being such to force said concentric rings apart and against the interior of said chamber in response to axial thrust on said apparatus.

2. The apparatus as defined in claim 1 wherein said concentric rings are sized to enable relative sliding movement therebetween.

3. The apparatus as defined in claim 2 wherein said concentric rings are sized to provide a radial clearance therebetween of less than about 5 mils.

4. The apparatus as defined in claim 2 wherein said concentric rings are sized in relation to each other to provide a radial clearance therebetween of from 0 to 2 mils.

5. The apparatus as defined in claim 2 wherein said one surface is faced with a hard-facing alloy.

6. The apparatus as defined in claim 1 wherein said bearing rings are composed of a bearing metal having a Brinnell hardness less than about 100.

7. The apparatus as defined in claim 6 wherein said bearing metal is a bronze alloy.

8. The apparatus as defined in claim 1 wherein said plastic material is a fluoroplastic.

9. The apparatus as defined in claim 5 wherein said fluoroplastic is polytetrafluoroethylene.

10. A pipe hanger for rotatably suspending a pipe string from a supporting structure in a well which comprises: a stationary support member adapted to be secured to said supporting structure; a rotating member adapted to suspend said pipe string, one of said members having an annular groove formed therein, and the other of said members having an annular end portion positioned in said groove, said groove and said end portion presenting axially spaced and transversely disposed surfaces; a bearing assembly mounted in said groove between said surfaces and including a plastic ring and two concentric metal rings positioned in said groove to substantially cover the radial spaces between said end portion and the inner and other walls of the groove to prevent excessive extrusion of the plastic ring.

11. The pipe hanger as defined in claim 10 wherein said metal rings are composed of a bearing metal having a Brinnell hardness less than about 100.

12. The pipe hanger as defined in claim 10 wherein said plastic ring is composed of a fluoroplastic.

13. The pipe hanger as defined in claim 12 wherein the fluoroplastic is polytetrafluoroethylene.

14. The pipe hanger as defined in claim 10 wherein said metal rings are sized to provide a radial clearance therebetween of less than about 5 mils.

15. The pipe hanger as defined in claim 14 wherein said radial clearance is between 0 and about 2 mils.

16. The pipe hanger as defined in claim 10 wherein said end portion positioned in said groove is faced with a hard-facing alloy.

17. An apparatus for rotatably suspending a liner in a case bore which comprises: a stationary member having an axial opening formed therein; means for securing said stationary member to the interior of the well casing; a rotatable member having a tubular portion extending through said opening formed in said stationary member, the lower end of said tubular portion being adapted to be connected to said liner, and a flanged portion having a downwardly opening, annular groove formed therein, said stationary member having an upper end portion disposed in said groove; a plastic ring mounted in said groove above said end portion; and two concentric metal bearing rings positioned in said groove to substantially cover the radial space between said end portion and the walls of said groove to prevent excessive extrusion of said plastic ring.

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